FOREST, RANGE, AND WATERSHED MANAGEMENT PROBLEMS

in

WESTERN COLORADO

(A Problem Analysis)

By

G. T. Turner, E. J. Dortignac, and C. W. Doran

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Rocky Mountain Forest and Range Experiment Station

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INTRODUCTION

This report portrays the more important problems of land management in western Colorado, particularly as they relate to forest and range land. Its purpose is three-fold: (1) to provide an inventory of natural resources and establish their relative importance to the present and future economy of the region; (2) to define and evaluate the problems associated with the use and development of land and water resources; and (3) to provide a basis on which to plan a sound research program.

The Western Slope, as considered here, includes that part of Colorado west of the Continental Divide. It occupies over 24 million acres, or more than a third of the State. It is a mountainous region with elevations ranging from 4,500 to more than 14,000 feet. About 70 per cent of the stream flow produced in the Colorado River Basin arises within its boundaries. Three-fourths of the area provides

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1/ Range Conservationist, Forester, and Range Conservationist, respectively, Rocky Mountain Forest and Range Experiment Station, maintained by U. S. Department of Agriculture, Forest Service, in cooperation with Colorado A & M College, Fort Collins, Colorado.

forage for livestock and big game, and one-fifth of the land supports stands of merchantable timber. Cultivated lands are confined to comparatively level areas that may be irrigated or dry-farmed. Vast deposits of minerals, including coal and oil, are important to the local and national economies. The scenic beauty of western Colorado, together with its cool summer climate and excellent hunting and fishing, attracts thousands of vacationists each year.

Two-thirds of the land in western Colorado is publicly owned. The federally administered land is divided nearly equally between national forests and grazing districts of the Bureau of Land Management. National forests include most of the important water-yielding area above 8,000 feet, most of the commercial timber land, and much of the land grazed by livestock during summer months. Land administered by the Bureau of Land Management is located at lower elevations and is used primarily for spring-fall and winter grazing. Privately owned lands also are located mainly at the lower elevations, and include both range and cropland. Accelerated erosion is commonly more severe and prevalent on lands which lie below 8,000 feet. Low elevation lands are the primary sediment-yielding areas.

The need for Western Slope water, both within and beyond the Colorado River Basin, is steadily increasing. To assure an adequate and dependable supply of usable water, greater knowledge of watershed management is required. Water storage is already seriously affected by sedimentation. Forage production is about half of potential capacity because of range deterioration. Furthermore, continued economic, social, and recreational development on the Western Slope demands improved management of the water, soil, forage, and timber resources; wise use of its minerals,

and better balance in agricultural enterprises.

To simplify the classification, analysis, and eventual solution of land-management problems, a break-down into elevational zones is used. These zones are (Fig. 1) the upper zone, 8,000 feet and above; the intermediate zone, between 6,000 and 8,000 feet; and the lower zone, between 4,500 and 6,000 feet. Physical features of each zone have been largely responsible for the type of past use and development of the land resources, and have an important bearing on the nature and magnitude of problems.

The more important problems revealed in the analysis are described below. Conditions responsible for these problems are discussed more fully in the apperdix.

IMPORTANT LAND-MANAGEMENT PROBLEMS OF THE WESTERN SLOPE

Soil stabilization on deteriorated rangelands

About one-third of the Western Slope is eroding rapidly (Fig. 2).2/ Most of the land on which soil erosion is severe or excessive lies below 8,000 feet where annual precipitation ranges from 8 to 20 inches. Due to limited precipitation these lands naturally support a thin plant cover. However, close grazing use has reduced this cover until it is no longer effective in holding the soil in place. Steep slopes are common. Soils over wide areas are derived from highly erosive shales. In many places grasses and herbs have disappeared.

2/ Prepared on the basis of published and unpublished material of the Soil Conservation Service, range and soil-erosion surveys of the Forest Service, and observations by staff members of the Rocky Mountain Forest and Range Experiment Station.

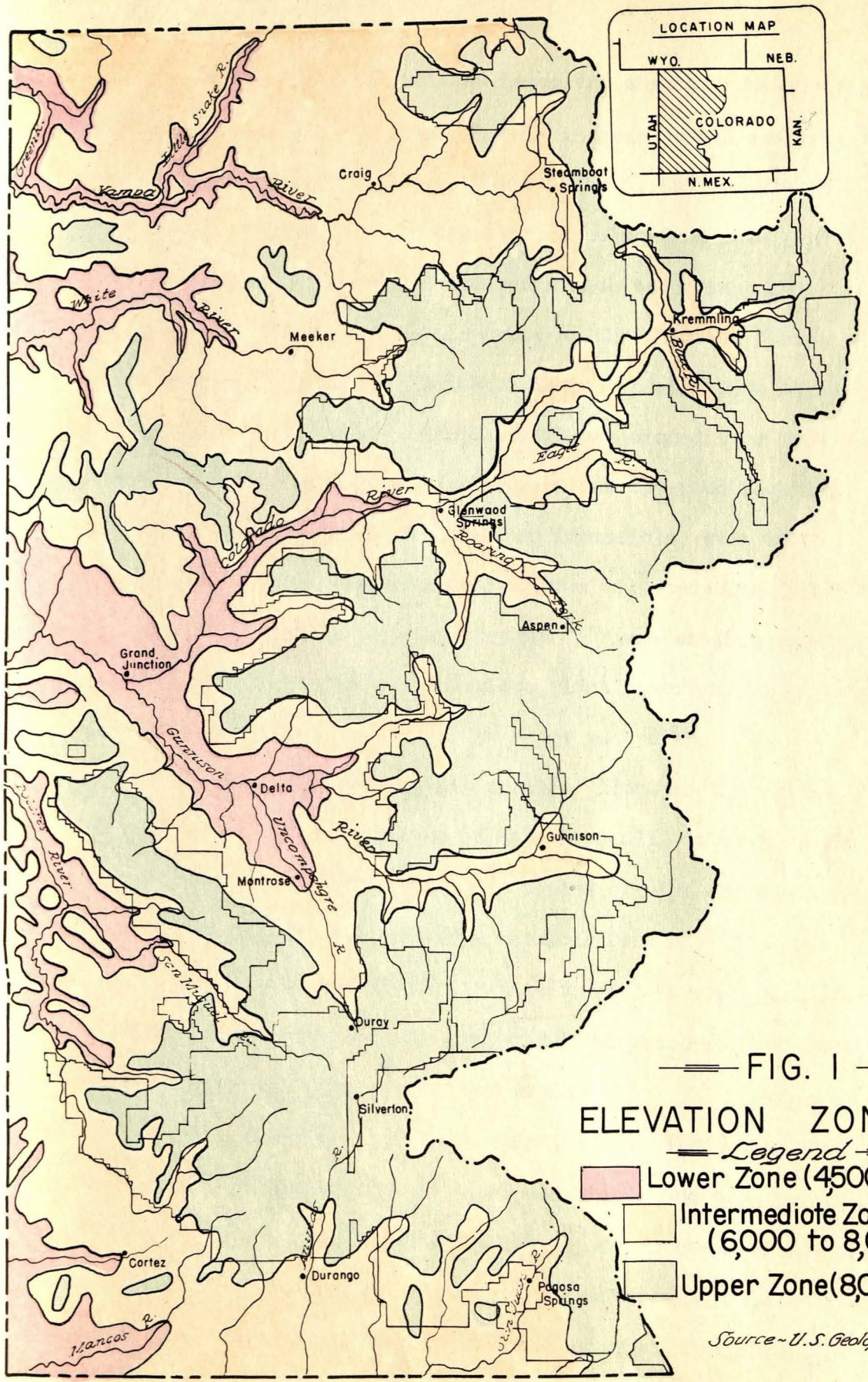

FIG. 1

ELEVATION ZONES

Legend

Lower Zone (4,500 to 6,000 ft)

Intermediate Zone (6,000 to 8,000 ft.)

Upper Zone (8,000 to 14,000 ft.)

Source - U.S. Geological Survey

and only bare soil is found between trees and shrubs. Deterioration of the plant cover has resulted not only in accelerated erosion, but in greater surface runoff, less productive land, and sedimentation of streams and reservoirs. Sediment originating from low-lying lands of the Western Slope presents a serious menace to present and future agricultural and industrial developments on the Colorado River.

The problem of soil stabilization is most critical in the pinon-juniper and sagebrush types where top soil has eroded from thousands of acres. Establishment of a protective plant cover on such sites in a reasonable time may be difficult or impossible, even under intensive management. Mechanical structures will undoubtedly be needed to help solve the problem in certain areas. Where erosion has been less severe it appears that an effective plant cover may be restored through improved grazing practices or range reseeding.

Solution of the problem is not simple. Although the volume of forage produced by these lands is relatively small, it is in great demand for livestock during spring months and by big game during the winter. Game managers recognize the critical forage problem and are attempting to alleviate it through more intensive harvest of the game crop. Until grazing pressure is reduced the herbaceous plant cover will have little opportunity to thicken and thrive.

In general, deterioration of the plant cover within the upper zone has been less severe than at lower elevations and accelerated erosion is not as prevalent. Most of the aspen, mountain-brush, and alpine grassland types are in satisfactory condition in regard to soil stabilization. However, extensive areas of mountain grassland 3/

3/ Includes grasslands and parks within timbered areas above 8,000 feet.

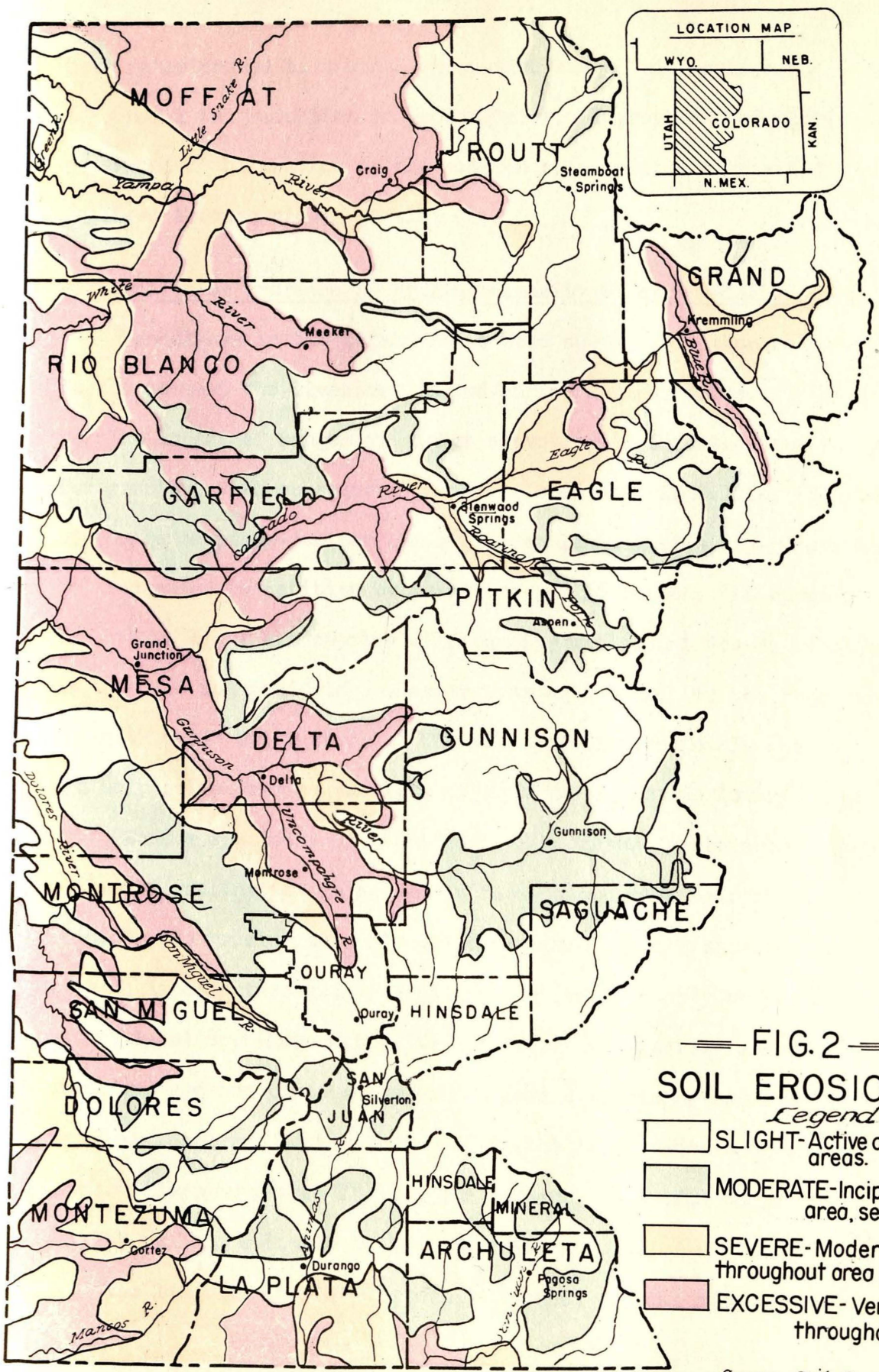

FIG. 2

SOIL EROSION

Legend

- SLIGHT- Active only in localized areas.
- MODERATE- Incipient throughout area, severe locally.
- SEVERE- Moderately active throughout area excessive locally.
- EXCESSIVE- Very active throughout area

Source: Soil Conservation Service, U.S. Forest Service

have deteriorated to a mixed grass-weed stage, with subsequent loss of topsoil and reduction in productivity. Improvement of the plant cover and stabilization of the soil on such areas can generally be realized through proper grazing use.

Restoration or increase of grazing capacity of spring-fall ranges

Rangelands in the intermediate zone supply less than half enough forage to meet the livestock demand during spring months. This often results in use of ranges at higher elevations before they are ready for grazing, with subsequent damage to soil and plant life. Shortage of forage on pinon-juniper and sagebrush lands limits big-game numbers and increases competition between game and livestock. It appears that these lands are capable of producing at least twice as much forage as they are now producing. Restoration or increase in their grazing capacity would bring seasonal forage supplies more nearly into balance and help solve grazing problems in both the upper and lower zones.

Greater knowledge of the effect of different periods and intensities of grazing use is needed to formulate a plan to restore and maintain the grazing capacity of these lands. Range reseeding may play an important role in increasing the forage supply on the more favorable sites. More extensive use of reseeded acreages should tend to reduce grazing pressure on native forage producing lands and aid in their recovery. Attempts to reseed the lower rangelands on the Western Slope have been limited and research is needed to test and develop methods suitable to local conditions.

The lower portion of the mountain-brush type is also used as spring

and fall range. The herbaceous plant cover here is generally in better condition than in sagebrush and pinon-juniper types. However, brush thickets limit grazing use to the more accessible areas and reduce the grazing capacity of the type. Economical methods of brush control need to be developed, followed by investigations of various systems of management that will maintain a more desirable type of plant cover.

Evaluation of range-watershed condition and trend

Inability and reluctance of land managers, livestock operators, and other responsible individuals to recognize the condition and health of grazing lands have undoubtedly been responsible for many local range and watershed problems. Deterioration of the soil and plant cover is often slow and difficult to detect in the early stages. Consequently, many watersheds have been damaged severely before the need for remedial action has become apparent.

Criteria for judging condition and trend have not been developed or adapted for use on the Western Slope, yet they are fundamental to proper management of all rangeland grazed by livestock and big game. The optimum kind, amount and composition of plant cover for watershed protection and grazing use by livestock and wildlife need to be determined for each major grazing type. Soil conditions also should be evaluated. It appears that the need is most urgent in the upper zone, especially in the mountain grassland type, where the vegetative cover is complex and difficult to evaluate in the light of present knowledge. This type contains most of the key grazing areas for cattle on summer range. A large bunchgrass, Thurber fescue, was formerly abundant in mountain grassland parks, but as a result of past use it has been replaced

in many areas by brome grass, wheatgrass, needlegrass, bluegrass, and various weeds. Some stockmen contend that these plants provide better forage than Thurber fescue. Should management be aimed at restoring Thurber fescue, or are other plants just as valuable for forage production and watershed protection?

Criteria are also urgently needed for the pinon-juniper type to aid in evaluating range-watershed conditions. Which conditions of soil and plant cover provide satisfactory watershed protection and how may they be achieved? Is vegetation alone a reliable indicator of trend in watershed condition, or must other factors be considered and evaluated? Such information is essential and fundamental to proper management of the type.

Livestock and big-game management

An important problem of the local livestock industry is how to make more efficient use of the native forage supply. It consists of two phases: (1) how to utilize the range so as to conserve the resource; and (2) how to use the forage crop most profitably.

The problem of livestock distribution is encountered on nearly all cattle ranges and on many sheep ranges. Because of the mountainous nature of western Colorado, grazing use is commonly concentrated in the more accessible areas. This frequently results in overuse and damage to portions of the range while other areas are only lightly grazed. Management plans, if properly made and carried out, should help to correct this situation. Further research may also be needed to determine how range units may be used more uniformly.

Related to the problem of livestock distribution is the problem of managing ranges that contain several types of plant cover, such as grassland, mountain brush, and aspen. When and how closely should each type be grazed? Should they be grazed separately where possible or in combination? Which types provide forage for game animals and how much forage should be reserved for game use? Present use varies greatly, depending on the kind and class of stock, availability of forage, season of the year, and other factors.

Cattle and sheep generally graze separate ranges in western Colorado (Fig. 3). Ranges that are grazed by sheep year after year commonly support a denser grass cover than comparable ranges grazed by cattle. On the other hand, many cattle ranges now produce mainly weeds as a result of past abuse. In view of the forage preferences of the two kinds of livestock, it might be desirable to change or alternate use between cattle and sheep to hasten range recovery and maintain a desirable mixture of forage plants. The effect of such use on both range and livestock production deserves investigation.

Depletion of the plant cover in the pinon-juniper and sagebrush types is often attributed to deer that have become more numerous during the past 25 years. Information is needed on grazing habits of deer, sheep, and cattle to determine in what manner and degree they compete for forage. Such a study is being conducted at the Little Hills Experiment Station near Meeker by the Colorado Game and Fish Department. Similar studies are needed on summer rangelands. A thorough investigation of livestock and big-game management in the pinon-juniper, sagebrush, and mountain grassland types would go far toward improving watershed conditions, stabilizing local livestock enterprises, and maintaining suitable habitats for wildlife in western Colorado.

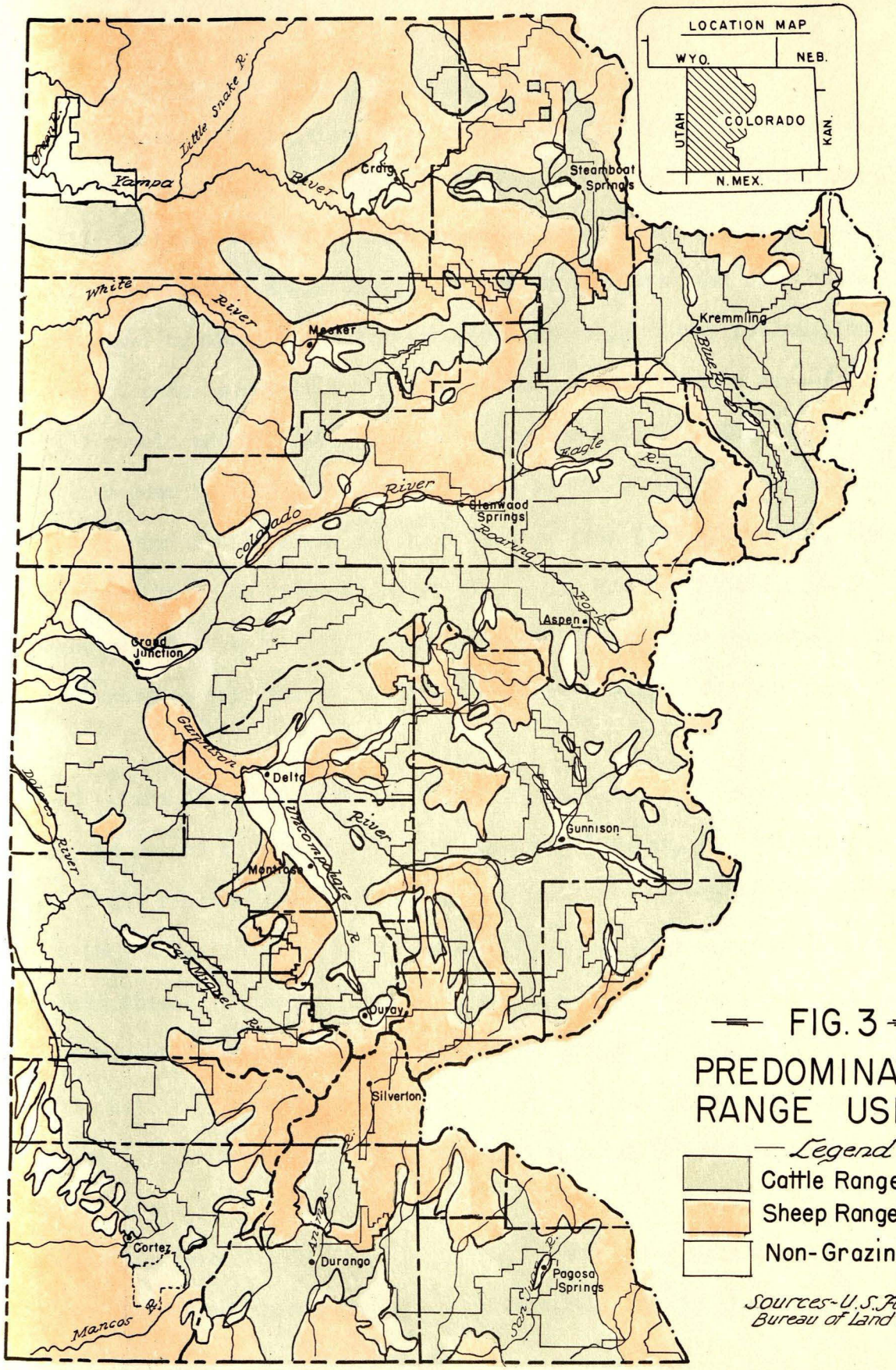

FIG. 3

PREDOMINANT RANGE USE

Legend

Cattle Range

Sheep Range

Non-Grazing Land

Sources-U.S. Forest Service
Bureau of Land Management

Maintenance or increase of usable water supplies

It is generally recognized that available water supplies will eventually limit the development of the Colorado River Basin. While the water supply is usually adequate to meet present demands, local shortages sometimes occur due to lack of storage facilities. Present uses deplete the flow of the Colorado River by about 7 million acre-feet annually. When reclamation projects now under construction are completed, only 5 million acre-feet per year will remain unused. This amount is considerably less than the 9 million acre-feet needed to supply projects planned by the Bureau of Reclamation and other agencies within and adjacent to the Basin (32) 1/Moreover, these estimates are based on average annual flow which may be misleading. During the 10 consecutive years (1931 - 40) of lowest stream flow recorded, water yield amounted to only three-fourths of the average flow for the past 47 years.

The future demand for water on the Western Slope needs further study, not only in regard to agricultural and industrial needs, but relative to municipal and recreational requirements. Almost two-thirds of the irrigable acreage in western Colorado is now receiving water, though not always in ample quantities. There is increasing evidence that future industrial developments will require large quantities of water. A paper-pulp mill is needed to utilize beetle-killed timber. The growing need for oil and depletion of present petroleum supplies will no doubt accelerate development of the oil-shale industry.

Oil shale deposits in western Colorado cover 1,655 square miles, and estimates place the recoverable oil from the shale at 270 billion barrels.

1/Figures in parenthesis refer to literature cited.

This is seven times the total production in the United States to date. Hydrogenation of coal is another possibility. These and other uses could soon exhaust available water supplies.

Although it is doubtful that precipitation over large areas can be altered appreciably by man, the amount and quality of water delivered as stream flow may be influenced considerably by watershed management. The present kind and condition of plant cover on many areas probably does not result in the greatest possible yield of usable water. The possibility that water supplies may be increased through careful timber cutting has been indicated in studies such as the Wagon Wheel Gap experiment on the Rio Grande in Colorado (1) and more recent studies at Fraser, Colorado (28).

The best opportunity for increasing water yield lies in the spruce-fir and lodgepole pine types where most of the winter snow accumulates. Partial cutting of timber stands now appears to be the most promising method, but the value of establishing blocks of timber for trapping snow on wind-swept mesas and plateaus should also be investigated. Research is needed to determine the relative values of the various timber types for water yield and how they should be managed to insure the greatest supply. Similar studies are needed in other vegetation types of the upper zone, particularly in the mountain-brush and alpine grassland types. The desire of stockmen to eradicate or control brush to increase the grazing capacity of the range is steadily mounting. The effect of such control on watershed values should be determined. What is the relative consumptive use of water by shrubs, grass, and weeds? How may the most valuable type of plant cover be maintained?

Contribution of the alpine grassland type to stream flow is not adequately known. It is probably that the area above timberline, though small in aerial

extent, contributes a large portion of the annual stream flow. It may be the key area in promoting late summer flow. The relationship between vegetation, soil and water yield in this belt needs further study.

Regulation of stream flow

Regulation of stream flow is needed to minimize flood damages and to provide ample water supplies for irrigation and other purposes during late summer. More than half of the stream flow of the major streams occurs during May and June. Large quantities of water are not utilized because of inadequate storage facilities, the present capacity of reservoirs amounting to less than a million acre-feet. Consequently, the yield of farm crops is often reduced as a result of insufficient water during the latter part of the growing season. The problem is important both in the intermediate zone where rainfall often causes floods, and in the upper zone where snow-melt furnishes most of the late-season flow.

Mechanical structures offer only a partial solution to the problem. To obtain the highest possible water yields during late summer, the soil and plant cover must be maintained in a condition that will promote maximum accumulation of snow and rapid infiltration of water into the soil. The exact nature of these conditions is not known, but with improved watershed management it is probable that substantial regulation may be accomplished.

Judging from past research, timber cutting may alter the distribution of stream flow. In the Wagon Wheel Gap experiment, timber cutting increased the flow during spring months about 22 per cent, whereas average annual stream flow increased only 15 per cent. Investigations at the Fraser Experimental Forest will provide information concerning optimum conditions of coniferous forests for snow retention and control of runoff. Further studies will be needed to determine how these findings apply to other portions

of the Western Slope.

Forest management and utilization

One of the most important forest problems is how to utilize the timber of the region more efficiently. Many timber stands are now over-mature and decadent. Present methods of logging and milling result in waste of much wood, including small logs, tops, slabs, and inferior species. Although there is a steady and growing demand for lumber, such by-products as posts, mine props, and fuelwood often find no ready market. New uses for this wood need to be explored and developed. Salvage of 4 billion board feet of beetle-killed spruce presents an urgent problem. The value of aspen for pulp, and the feasibility of utilizing this species along with spruce should be investigated. Aspen also offers possibilities for other uses such as matches and excelsior.

Observations and present studies indicate that timber harvesting according to approved methods does not generally cause a large amount of erosion or deterioration of soils. There is some indication that logging may cause surface runoff. This is particularly true in regard to roads and skid trails; here soil erosion may also be a problem.

Better information is needed on the management of lodgepole pine and spruce-fir stands for maximum sustained production consistent with good watershed management. What methods of cutting are best adapted to each type under different site conditions? Which methods insure satisfactory reproduction of desirable species? Under what conditions are weeding or thinning justified? What is the growth potential of various timber stands? How should the stands be managed to minimize loss from bark beetles, other insects, and diseases? Answers to some of these questions are expected from

studies being conducted at the Fraser Experiment Forest. How these stands are managed will largely determine the role local forests will play in the future economy of the region, both from the standpoint of timber production and watershed protection.

Aspen now occupies over 2 million acres that may be capable of growing conifers. Should these lands be managed to encourage growth of trees more valuable for timber? If so, how? Is grazing within aspen stands detrimental to the growth of timber or to watershed values? The relative values and limitations of aspen sites for timber, water, and forage production need to be investigated in order that conflicts in use may be avoided.

Control of noxious and poisonous plants

Extensive areas of range land are dominated by plants of little value for grazing. Among the more common in the intermediate and lower zones are sagebrush, scrub oak, pinon pine, and juniper. At higher elevations sneezeweed, hairy goldaster, tarweed, false hellebore, wyethia, and other weeds occur locally in nearly pure stands. Most of these plants have increased in abundance as the result of over-use of more desirable plants. The grazing capacity of the land has declined accordingly. Even where grazing pressure is reduced, range recovery is severely retarded due to the competition of inferior plant species.

Brush-control measures in Texas, Oklahoma, California, and other western states have resulted in substantial improvement of the grass cover. On the Western Slope several attempts to control sagebrush by various methods have been successful, but in general the feasibility and desirability of plant control have not been explored. Newly developed herbicides, such as 2,4-D, are

being used more and more extensively with little knowledge of their ultimate effect on soil and plant cover. Practical guides for plant control measures are needed to safeguard range and watershed values.

Control of poisonous plants is also an important problem. It is estimated that cattle death losses in areas infested with larkspur are sometimes as high as 5 per cent each year. Sheep losses from sneezeweed may amount to 10 per cent on heavily infested ranges. Occasional losses occur from death camas, whorled milkweed, horsebrush, timber milkvetch, water hemlock, pingue, and other poisonous plants. Cheap and efficient methods of control are needed.

Rodent control

Rodents affect the health and productivity of forest and range land much more than is generally realized. For example, pocket gophers, rabbits, mice, ground squirrels, prairie dogs, and marmots consume substantial quantities of forage and may retard range improvement by destroying seed that might otherwise produce new plants. Comparatively little is known about the inter-relationship of rodents and their environment, how they may be controlled effectively, and what their normal population should be.

Pocket gophers are especially destructive because of their burrowing habit. These rodents have increased rapidly during recent years, both as a result of more intensive predator control and greater abundance of weeds on the range, which makes up the bulk of their food. In the spring many deteriorated grasslands of the upper zone have the appearance of freshly plowed fields due to gopher activity. Gopher control through trapping and use of poison bait has generally proved to be costly, and

impractical. Greater knowledge of the relationship between gopher populations and predators, grazing management practices, and range and watershed conditions is needed to solve the problem.

Judging land capability

Suitability of uncultivated land for various purposes is determined largely by inherent characteristics of soil, topography, climate, and plant cover. These factors should govern even more closely than is now the case, the manner in which the land is used for a given purpose. The object of judging land capability is to classify the land according to the use or uses to which it is best adapted and to define the limitations of such use. Forest and range lands need to be classified according to their ability to yield water, timber, and forage under uses that will maintain or restore site productivity. For example, it is generally known that grazing use of steep slopes, south and west exposures, and sparsely vegetated sites must be closely regulated to prevent damage to the watershed. Methods and criteria for judging the capability of land under various situations should be developed by research. Studies of soil stabilization, water yield, and range condition will provide many of the answers, but unless land capability or site potential is considered and evaluated separately many gaps will be left in existing knowledge. These criteria will also help to determine how widely and to which situations research findings may apply.

CLASSIFICATION OF PROBLEMS BY ZONES

Ten broad but important problems have been listed. Some of these are limited to one elevational zone while others are common to all zones. However, each zone may be considered a problem area due to outstanding differences in physical characteristics and land uses. The more important characteristics of each zone, together with its outstanding problems and their inter-relationships, are discussed below.

Upper zone

Ranging from 8,000 to 14,000 feet, this zone occupies almost half of the Western Slope. The topography is rugged near the Continental Divide, but mesas and plateaus are common in the western portion. Annual precipitation varies from 20 to 35 inches, most of which falls as snow. Although the growing season is short, the climate supports a fairly dense cover of vegetation. Soils are generally stable and productive. Over half the area is forested, interspersed with grassland parks and meadows. Brush occupies the slopes below the timber belt, while alpine grasslands and barren mountain peaks occur at higher elevations.

The physiographic characteristics of the upper zone are conducive to high water yields, timber production, recreation, and summer grazing by livestock and big game. Many areas serve all purposes. As would be expected, conflicts frequently arise among the different uses. Improper grazing use may impair the capacity of the land to yield maximum flows of clear water. Dense stands of timber and brush may limit stream flow through interception of snow and use of water. Grazing may inhibit reproduction of the forest cover; or, on the other hand, trees may invade grassland parks,

reducing the value of the land for grazing.

Primarily, the upper zone is valuable for its water supply and land use should be regulated to conform with the requirements of good watershed management. Among the problems of the upper zone, two are of greatest importance: (1) maintenance or increase of water yield, and (2) regulation of stream flow. It is probable that the major solution of these problems lies in the management of areas above timberline, forested slopes, and brush-covered areas at high elevations.

Forage production is also important in the upper zone. Lands suitable for summer grazing are a key link in many livestock operations, and livestock production is the most important agricultural enterprise on the Western Slope. A recent survey shows that mountain grasslands are producing far less forage than they should be. Weeds, shrubs, and inferior grasses have replaced the better grasses over wide areas. Improvement of these lands will depend largely on the solution of problems related to: (1) livestock and big game management; (2) range condition and trend; (3) noxious plant control; (4) rodent control; and (5) range rehabilitation through artificial reseeding. Present knowledge indicates that management of grazing land for maximum forage production will result in adequate watershed protection.

Timber is a third important crop of the upper zone. Because the timber is relatively small and inaccessible in many areas, it has contributed little to the past economy of the region. In general, the forests of this region are probably more valuable as watershed cover than for timber production. Judicious cutting of mature stands may be expected to increase the yield of both wood and water. Development of more efficient methods of timber harvesting and

utilization would promote better forest and watershed management and increase the usefulness and value of timber stands.

The problem of judging land capability is especially important in the upper zone because of the multiple uses involved. Determining the conditions under which grazing, timber cutting and other land uses should be restricted or modified so as to conserve the soil and water resources is an important job for research.

Intermediate zone

This zone occurs between 6,000 and 8,000 feet and occupies about one-third of the Western Slope. It includes the lower mountain slopes as well as hills and plateaus. Annual precipitation varies from 14 to 20 inches, some of which occurs as cloudbursts. Soils are derived principally from sedimentary rocks and they tend to erode easily. The native vegetation consists mainly of mountain-brush, pinon-juniper, and sagebrush types. Herbaceous plant cover is generally thinner here than in the upper zone, and in the pinon-juniper type it is extremely sparse.

Although the intermediate zone produces little usable water, it represents an important part of Western Slope watersheds. Soil erosion is severe in many areas, especially on sagebrush and pinon-juniper lands. Contribution of sediment from those lands is much greater than that from the entire upper zone. Sediment from the low-lying lands not only reduces the storage capacity of reservoirs but mixes with the normally clear water that originates in the upper zone. The success of the huge engineering program proposed for the Colorado River Basin depends largely on how well erosion is controlled on these and similar lands within the Basin.

Regulation of streamflow is also important in this zone. Flash floods occur frequently as the result of cloudburst storms. The severity of such floods could be reduced appreciably if the water absorption capacity of the soil were increased.

Lands of the intermediate zone have suffered a drastic decline in grazing capacity due to uncontrolled grazing use in the past. This has resulted in a serious shortage of forage for livestock during spring months and for big game during the winter. The problem of improving the plant cover of these lands is coupled directly with the problem of stabilizing the soil and regulating stream flow. More extensive use of irrigated pastures and reseeded lands during spring months may be necessary to reduce the grazing pressure on native forage producing lands and aid in their recovery. Control of noxious or low-value plants such as sagebrush, scrub oak, pinon pine and juniper is also important where they limit herbage production or interfere with the establishment of a satisfactory watershed cover.

Other problems of the intermediate zone include: (1) evaluation of range condition and trend; (2) livestock and big game management; and (3) judging land capability. Solution of these problems can be expected to aid materially in stabilizing the soil, reducing flood damages, and increasing forage production. Proper land management in the intermediate zone will do much toward alleviating the problems of the upper zone.

Lower zone

This zone occupies nearly 4 million acres at elevations of 4,500 to 6,000 feet. It represents less than 15 per cent of the Western Slope and differs from the intermediate zone in having a warmer and drier climate. The annual precipitation of 8 to 14 inches supports salt-desert shrubs, pinon-juniper, sagebrush and greasewood. Range lands are used principally for winter grazing

and all cultivated lands are irrigated.

Erosion in the lower zone is more severe than at higher elevations due to the thin cover of vegetation the climate will support. Over half the soils are derived from highly erodible shales. Wasatch and Mancos shale predominate and form extensive areas of badland topography. These areas yield excessive runoff and sediment during the few storms that occur each year. As in the intermediate zone, past grazing abuse has resulted in deterioration of the plant cover and increased erosion.

PROPOSED RESEARCH PROGRAM

Location of Projects

In general, first priority is given to problems of the intermediate zone. It is the area in which erosion and sediment production are most critical, where forage production has sharply declined, and on which flood-producing storms occur most frequently. It is the key area for sound land use in western Colorado and promises to offer large returns from the investment of research funds.

Second priority is given to problems of the upper zone where water yield is potentially the most important to the full development of the Colorado River Basin. This zone represents a key link in many livestock operations; it is important as a source of timber and is valuable for recreation.

Third priority is given to the lower zone where problems are similar to those in the intermediate zone, but where climate and soil limit the speed with which research results may be obtained. Many research projects undertaken in the intermediate zone will have direct application in the lower zone.

Coordination of research efforts and objectives

Many land use problems of western Colorado deserve immediate attention. However, only a few of the more urgent ones may be investigated at the present time with the funds available. To make the most efficient use of these funds a coordinated program of range and watershed management research is proposed. Many of the land management problems are inter-related and may be studied simultaneously. The objective is to develop a well-balanced research program that may be altered in the light of additional knowledge and changing conditions.

In the intermediate zone, important objectives are to stabilize the soil, reduce surface runoff, and increase forage production. It appears that these objectives may be attained largely through establishment of a more effective plant cover, supplemented where necessary with mechanical structures.

In the upper zone, primary objectives are to increase or maintain water yield and forage production, and to regulate stream flow through management of the soil and plant cover. Studies involving timber cutting or brush control should be designed to measure changes in forest growth, forage production, water yield, and sedimentation. Studies pertaining to grazing practices and management of grazing animals should be closely coordinated with watershed studies.

Development of criteria for determining the best and proper use of wild lands will require full consideration of all values involved. Efficient use of our natural resources may be realized only when conflicts in use are eliminated or reduced to a minimum.

Investigations now underway

The following studies are now being conducted at the Upper Colorado River Research Center.1/ They are aimed at solving some of the more important problems and should be continued to completion.

Intermediate zone

1. Evaluation of range-watershed conditions in pinon-juniper and sagebrush types (infiltration-erosion tests).
2. Adaptability of plants for reseeding in sagebrush and pinon-juniper types (row plot trials).
3. Evaluation of methods for reseeding the above types (range plot trials).
4. Control of sagebrush, scrub oak, pinon pine and juniper with chemicals.

Upper zone

1. Evaluation of range-watershed conditions in mountain grassland and aspen types (infiltration-erosion tests).
2. Adaptability of plants for reseeding mountain grasslands (row plots).
3. Evaluation of methods for reseeding mountain grasslands (range plots).
4. Control of noxious plants, including sneezeweed, hairy goldaster, tarweed, and wyethia by chemical and mechanical means.
5. Influence of cattle and pocket gopher control on range forage production.
6. Judging condition and trend of mountain grasslands.

Lower zone

1. Adaptability of plants for reseeding desert-shrub type (row plots).

1/ A branch of the Rocky Mountain Forest & Range Experiment Station, with headquarters at Delta, Colorado.

Investigations proposed for the near future

Listed below are new studies that may be undertaken within the next few years with present funds and manpower.

Intermediate zone

1. Selection and calibration of small experimental watersheds for study of (2).
2. Effectiveness of various treatments and land management practices in stabilizing the soil, reducing surface runoff, and increasing the grazing capacity of sagebrush-pinon-juniper lands.
3. Effect of noxious plant (primarily scrub oak) control on grazing capacity and watershed values.
4. Relation of site factors to range reseeding.
5. Evaluation of range condition and trend in sagebrush, pinon-juniper, and mountain-brush types.

Upper zone

1. Effect of different periods and degrees of grazing use in mountain grassland and aspen types on grazing capacity, cattle weight gains, and watershed values.
2. Relative use of water by scrub oak and native herbaceous-plant cover (primarily soil moisture studies).
3. Response of reseeded species to grazing use.
4. Effect of noxious plant control on grazing capacity and watershed values.

Lower zone

No new studies are proposed for the immediate future.

Additional studies recommended

Listed below are studies needed to solve related problems in forest, range, and watershed management. These studies should be considered in planning a long-range research program and undertaken as funds become available.

All zones

1. Criteria for determining proper use of important soils and vegetation types to safeguard watershed values.
2. Location and classification of specific flood- and sediment-source areas to effectively direct efforts of action agencies.
3. Soil erosion hazard under various land management practices.
4. Effectiveness of water spreading in reducing peak flows and sedimentation of streams.
5. Criteria for judging usability of range land by sheep, cattle, and big game, as related to grazing capacity.
6. Effect of different seasons and systems of grazing on range health and livestock production.
7. Methods of obtaining better livestock distribution on open range land.
8. Practical guides to management of reseeded areas.
9. Wildlife habitats and populations as affected by livestock grazing.

Intermediate zone

1. Relative contribution of sediment from slope and gully erosion and streambank cutting.
2. Methods of reducing gully cutting and deterioration of stream channels.
3. Criteria for judging range-watershed conditions in the mountain-brush type.

13. Measurement of growth and mortality in spruce-fir and lodgepole pine stands to determine practical cutting cycles.

14. Management of aspen stands for greater production of usable products.

Lower zone

Studies recommended for this zone are similar to those for the intermediate zone. Those pertaining to soil stabilization should receive first consideration after the more important problems of the intermediate and upper zones have been solved.

Justification

Research projects now underway or proposed for the near future are aimed at solving the more critical problems of range and watershed management. While problems of forest management are also important, most of them can be studied to better advantage at the Continental Divide Research Center. Furthermore, no funds are allotted for forest management investigations at the Upper Colorado River Research Center at the present time.

The program proposed for range management and reseeding is somewhat broader than that for watershed management. More funds are currently available for range studies, which generally receive greater local interest and support. Solution of the more important range problems can be expected to aid in solving the more critical watershed problems.

The proposed program calls for concerted efforts to improve range and watershed conditions in the intermediate zone. Primary efforts will be devoted to reseeding and plant control because of the apparent difficulty of improving these lands through management alone. Meanwhile, guides to proper management of sagebrush-pinon-juniper lands will be developed on a series of small experimental watersheds. Results of these tests may be

4. Effect of different grazing systems and practices in sagebrush and pinon-juniper types on range improvement, big game, and livestock production. (broad-scale test of results from range-watershed studies proposed for near future).
5. Relative economy of grazing native, reseeded, and irrigated pasture land during spring and fall months.
6. Relative contribution of streamflow from ponderosa pine type.

Upper zone

1. Methods of increasing stream flow during late summer months (test of most promising methods on watershed basis).
2. Methods of reducing peak flows from snow melt (watershed basis).
3. Effect of sheep grazing on health and productivity of alpine watersheds.
4. Effect of brush control on quantity, quality, and timeliness of stream flow (watershed basis).
5. Utilization standards for key plants in mountain-brush and alpine grassland types.
6. Evaluation of range condition and trend in the aspen type.
7. Management of sheep on high mountain range lands to improve range conditions and increase livestock production.
8. Effective methods of reducing damage caused by pocket gophers.
9. Control of larkspur and other poisonous plants.
10. Methods of logging and milling, and development of more and better uses for local forest products, to reduce waste.
11. Harvesting of mesa-type spruce stands to insure satisfactory restocking and growth of desirable species.
12. Management and harvest of bettle-killed spruce stands to promote restocking and growth of new stands.

applied on a broader and more practical scale as funds become available.

Certain studies are needed in the upper zone to maintain a rounded and well-balanced program. These studies will involve management of the native plant cover, principally on mountain grasslands, to improve range and watershed conditions. The grazing capacity of mountain grasslands, though far below its potential, is much greater than that of sagebrush-pinon-juniper lands. Stock water supplies are also more readily available. Consequently, experimental control of grazing animals is much less costly. Results of treatment are likely to be obtained, accepted, and applied in a much shorter time than on depleted rangelands at lower elevations. Cattle ranges are given preference over sheep ranges because they are generally in poorer condition, and cattle are more important to the local economy. Grazing trials in the upper zone may be completed by the time results of land treatment on small watersheds in the intermediate zone are available for testing on a broad scale.

Investigation of factors affecting water yield and stream flow from the upper zone preferably should be fundamental in nature during the next few years. After the basic principles and plant-soil-water relationships are more fully understood, the results of these studies may be applied and tested on large watersheds.

Possibilities for Cooperative Studies

Active cooperation with individuals and other agencies in solving problems related to range and watershed management will be encouraged. Most of the studies now being conducted are on a cooperative basis. The U. S. Fish and Wildlife Service has been cooperating with the Rocky Mountain Station in a study of pocket gophers during the past 10 years. Farmers and

ranchers, as well as the Bureau of Land Management and the Forest Service, are cooperating in range reseeding trials by furnishing the land, preparing seedbeds, or helping to fence experimental plots. Colorado A & M College, the Extension Service through 4-H Clubs, the Soil Conservation Service, Isaac Walton League, and local service groups are conducting or sponsoring reseeding tests. To avoid duplication of effort and make better use of funds available, special efforts are being made to coordinate these studies with those of the Upper Colorado River Research Center.

Various chemical companies are eager to test the effectiveness of their products in control of noxious plants and are often willing to supply chemicals without cost.

The Colorado Game and Fish Department is becoming more interested in range management and is expanding its research program. It is conducting a comprehensive study of deer, cattle, and sheep use on game winter range at the Little Hills Station near Meeker, and is initiating studies in range reseeding in various localities.

A demonstration of desirable range management and range improvement practices on a summer grazing allotment through cooperation of local ranchers with the Forest Service is also planned. Such a demonstration should prove valuable in testing research findings on a practical scale.

Opportunities for cooperative studies in watershed management are somewhat limited. However, efforts should be made to gain greater support of water users, the BLM and Forest Service in investigating and solving important local watershed problems.

APPENDIX

CONDITION OF NATURAL RESOURCES, AND FACTORS CONTRIBUTING TO PROBLEMS OF LAND MANAGEMENT

Social and Economic Aspects

Historical Development

The natural resources of western Colorado were little used by white man prior to 1880. Early settlement was hindered by hostile Indians, mountainous terrain, and lack of transportation. However, soon after the Indians were placed on reservations, white settlers rushed to claim the better lands for farming, ranching, and mining. Nearly half the present population was reached by 1900.

Mining of gold and silver was an important activity of the early days. It furnished the incentive for building railroads and growing farm crops to supply local needs.

The cattle industry expanded rapidly between 1880 and 1890. The lower, easily accessible ranges were soon overgrazed as little or no attention was given to proper range or watershed management at that time.

Irrigation farming, along with the growing livestock industry, also developed rapidly at an early date, especially in the valleys of the Uncompahgre and lower Colorado Rivers. Most irrigated land was used to produce hay for cattle during winter months, but conditions were also found to be suitable for fruit growing in the lower valleys.

The sheep industry did not assume importance until about the time of the first World War when conditions were less favorable for cattle raising and the prejudice against sheep had subsided.

Dryland farming in northwestern and southwestern Colorado also developed extensively about 1920. With the advent of drought years in the early thirties, many of the dryland farms in Moffat County were abandoned. This type of farming has been more successful in the San Juan Basin and is increasing at the present time.

Areas available for grazing during spring, fall, and winter months became smaller as the acreage of cropland increased. This resulted in even heavier grazing use of the more accessible range lands, where grazing was free and uncontrolled until the Taylor Grazing Act was passed in 1934. Scarcity of forage at lower elevations created excessive demands for forage on the higher, erodible slopes, and contributed to the damaging effects of floods and sedimentation. Unrestricted use of summer grazing lands before national forests were established also resulted in extensive damage to the soil and plant cover. Information on how to graze native range land to maintain healthy watersheds, increase forage yield, and obtain optimum livestock production has not kept pace with the development and needs of the people in the area.

Development of the forest resource has been hindered by rough topography, small size of the timber, and scattered nature of the stands. In general, only the more accessible stands have been cut-over. A recent epidemic of bark beetles killed 4 billion board feet of Engelmann spruce and lodgepole pine, which is probably more than the total volume harvested to date.

Regional Economy

The economy of the Western Slope, as in other arid communities of the west, is based primarily on an ample and reliable water supply. Irrigation

is required to grow most crops; livestock are dependent on supplemental feed from irrigated farms; towns and cities must be adequately supplied with good water; and industries rely on hydroelectric power to a certain extent. The development of the entire Colorado River Basin will be limited eventually by the available supply of usable water.

Livestock operations

Nearly one-third of the people of western Colorado are actively engaged in ranching and farming. 4/ In 1949 they sold livestock and livestock products valued at 42 million dollars. During the same year the value of all farm crops harvested was 41 million dollars.

Cattle raising ranks first in importance in the local livestock industry. In 1950 cattle numbered 371,000 head, compared with 751,000 sheep, according to U. S. census reports. On the basis of animal units 5/ there are over twice as many cattle as sheep. There are nearly five times as many cattle raisers as sheep raisers.

Most livestock operations are based on the use of seasonal ranges, often located many miles apart. This practice, coupled with the complex land-ownership pattern of western Colorado, makes it difficult for the livestock operator to adjust his operations to proper balance.

About 45 per cent of the cattle in the territory are permitted to graze on public domain, mostly during spring months (2). Nearly 60 per cent graze summer ranges within national forests. Changes in the rate of stocking or period of use of one seasonal range often require adjustments on other dependent ranges. While cattle ranges used at different seasons are generally

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4/ Total population is about 200,000 persons.

5/ An animal unit is used here as a mature cow or five sheep.

contiguous, permitted seasons of use are not always continuous. This results in technical trespass or forces the cattleman to move his livestock to other range.

According to a survey made in 1938-39 (12) 60 per cent of the sheep feed in western Colorado was obtained from private lands, 20 per cent from Taylor grazing districts, and 20 per cent from national forests. Seasonal ranges for sheep are often located many miles apart. Because of the great distances between summer and winter ranges, an annual sheep migration has developed. Two major migration routes and several smaller ones are used. About 100,000 sheep travel the northern route from the summer ranges of the Routt and White River National Forests to the winter ranges located in western Moffat and Rio Blanco counties. A second major route is followed by sheep moving to winter ranges west of Grand Junction and into Utah from summer ranges in the high country of the upper Colorado and Gunnison Rivers. Less extensive migrations occur between the San Juan summer ranges and winter ranges in Utah and New Mexico, and between ranges of the Routt National Forest and the Red Desert of Wyoming. These migrations and the use of lands in different ownerships create problems that are related not only to the conservation of the range resource but also to production of lamb and wool crops, taxation, census taking, disease and pest control, and other factors.

The typical grazing seasons for cattle and sheep are listed in Table 1. Grazing of spring ranges generally begins soon after plant growth has started. Because of the relatively long hay-feeding period for cattle, most ranchers are anxious to turn their livestock on the range as soon as possible. During severe winters hay supplies are generally exhausted, and, in the Gunnison and Yampa River valleys, cattle must be removed from the hay meadows before irrigation

starts. The grazing period on spring range is generally six weeks for cattle and two to three months for sheep.

Table 1 -- Typical grazing seasons for livestock.

Season	Cattle		Sheep	
	Average dates	Type	Average dates	Type
Spring	May 1 - June 15	Sagebrush pinon-juniper Irrigated pastures	Apr. 16 - June 30	Sagebrush Mountain brush pinon-juniper
Summer	Jun.16-Oct.15	Mountain grassland Aspen Mountain brush Ponderosa pine Sagebrush	Jul.1-Sep.15	Alpine and mountain grassland Aspen Mountain brush
Fall	Oct.16-Nov.30	Crop residue Sagebrush Mountain brush	Sep.16-Oct.31	Sagebrush Mountain brush Pinon-juniper
Winter	Dec.1-Apr.30	Hay	Nov.1-Apr.15	Desert shrub Pinon-juniper Sagebrush Supplements

Grazing of summer ranges begins between the middle of May and the first of July, and ends between September 15 and October 31, depending on local conditions. The grazing period for sheep is usually shorter than for cattle because sheep graze higher ranges.

Sheep are moved to fall ranges or pastures about the time of the first frost. Cattle make extensive use of crop residue and aftermath during fall months. This is supplied by harvested hayland and meadows, and by fields that

have grown crops of sugar beets, corn, beans, and small grains. Very little native forage is reserved for fall grazing by cattle. Marketing of livestock is active during this period.

Most cattle are fed hay throughout the winter. The majority of sheep rely on desert range in the lower zone of the Western Slope and in adjacent states. Efficient functioning of the range livestock industry depends on the use of vegetation types and watersheds so closely intergrated that what affects one ultimately affects all.

Farming

Nearly 800,000 acres of farmland are irrigated. Hay is the most valuable crop, accounting for one-third of the total value of all crops and one-half of the acreage harvested. Fruit, beans, small grains, and potatoes are other important crops.

About 300,000 acres are dry-farmed, of which one-half is located in the San Juan Basin and one-third in the Yampa River Valley. Pinto beans and small grains are the principal dry-land crops.

Mining

Mining is steadily increasing in importance as a source of wealth. The value of gold, silver, lead, copper, and zinc mined in 1946 amounted to over 13 million dollars. Vast deposits of bituminous coal are located in northwestern and southwestern Colorado. More than 3 million tons of coal were taken from western Colorado in 1946. Also found in comparative abundance are vanadium and uranium--raw material for atomic energy. During the war (1943) 5 million pounds of vanadium valued at 10 million dollars were produced. Western Colorado oil fields produced more than 15 million barrels of crude oil valued at more than

29 million dollars in 1947. The Rangely field is the largest in the Rocky Mountain region. Extensive beds of oil-bearing shale offer promise of becoming an important source of oil. Salt deposits amount to billions of tons, but are not being worked at the present time because of excessive depth. Gypsum reserves also constitute a large source of supply for future use when market conditions are more favorable. The Western Slope is truly a storehouse of mineral resources and its future economy and population undoubtedly will be greatly influenced by their development.

Lumbering

Harvesting of timber and milling of forest products are of relatively minor importance at the present time. Timber harvested within local national forests in 1951 amounted to 105 million board feet, or three-fourths of the total timber harvested in all the national forests in Colorado. However, the timber is small and logging costs and transportation rates are high, consequently lumber from this region cannot compete on national markets.

The demand for lumber produced locally is increasing, and may be expected to continue. Better sawmill equipment, together with proper seasoning and grading, would help to improve the quality of the lumber and expand local markets.

Development of new and better uses for other forest products is also needed. Beetle-killed spruce, as well as living stands of spruce, fir, and aspen, offer abundant sources of pulpwood and excelsior. Box and crating material are other possible uses.

Recreation

Western Colorado offers many and varied recreational opportunities. Its lofty snowcapped mountains, trout streams and lakes, beautiful forests, cool but sunny summer weather, big-game hunting, and winter sports attract

People from all parts of the nation. Income derived directly and indirectly from recreation adds substantially to the local economy.

As the various enterprises--grazing, farming, mining, timber production, industry, and recreation--are expanded by development of the Colorado River Basin, more people will live in the region. Better use of the resources will need to be made to meet the demands of the population, particularly for ample water supplies, food from livestock products, and materials for building and for industrial use. The economy of the region will be durable and balanced largely to the extent that the renewable resources make their optimum contribution and remain unimpaired in abundance and quality.

Land Ownership and Jurisdiction

Two-thirds of the land in western Colorado is owned by the Federal Government and nearly one-third is privately owned. (Table 2) Jurisdiction of federally-owned land is nearly equally divided between the U. S. Forest Service and the Bureau of Land Management. National forests occupy most of the upper zone, while grazing districts are located mainly at lower elevations in the western sector.

Table 2.--Land Ownership in Western Colorado (2)

Ownership classification	Acres	Per Cent
Federal		
National forests	8,356,563	34.0
Grazing districts and public domain	6,722,538	27.3
National parks and monuments	312,591	1.3
Indian reservations 1/	748,194	3.0
Power sites, stock driveways, etc.	275,424	1.1
Military reserves	59,441	0.2
Total federal lands	16,474,741	66.9
Private		
Farmland (all types)	6,775,936	27.5
Mineral land	331,399	1.3
Miscellaneous	51,844	0.2
Total private lands	7,159,179	29.0
Local government		
County and municipal	53,418	0.2
State	471,041	1.9
Total local government lands	524,459	2.1
Unclassified	482,988	2.0
Grand Total	24,641,367	100.0

1/ Federally administered.

Numerous problems have developed as a result of the land-ownership pattern and administration of federal land by different agencies. Uncontrolled grazing use of the public domain prior to 1934 resulted in severe deterioration of ranges and watersheds at low elevations. Many key areas, intermingled with federal land and often containing the only stock water available for large acreages, are privately owned. This presents a serious obstacle to proper use and administration of the surrounding lands. Mineral claims create similar problems. Some tracts of privately-owned grazing land are too small to form economic units. Consequently, they are usually overgrazed and watershed values are impaired. On the other hand, small and isolated tracts of public land are difficult and costly to administer.

Physical Characteristics

Physiography

Western Colorado is predominately mountainous in character. The terrain is rugged along the Continental Divide, while numerous plateaus and mesas characterize the landscape in the western sector. Among the larger plateaus are the Grand Mesa, Uncompahgre, White River, Roan, Yampa, and San Miguel, rising to elevations of 8,000 to 10,000 feet. Fringing the plateaus at lower elevations is an extensive network of foothills, developed in soft shales and sandstones and dissected by deep drainageways. Below this system of hills are basin-shaped valleys and rolling plains. Elevations range from 4,500 feet at the Utah state line to over 14,000 feet along the Continental Divide. Nearly one-half the land surface lies above 8,000 feet.

Physiography plays an important role in determining the kind and intensity of land use. Topography and elevation limit the acreage suitable for cultivation. Differences in local climate due to elevation and exposure are reflected in the native plant cover. The character of this cover, and the site on which it occurs, determine largely how it may, or should be used. For example, the growing period and availability of forage plants, as affected by elevation, determine seasonal grazing periods. The rugged topography of the upper zone makes harvesting of timber difficult and costly. Steep slopes hinder uniform grazing use and favor surface runoff and erosion. Thinning of the native plant cover on the steeper slopes of the intermediate zone is even more likely to result in accelerated erosion. Livestock concentration in the more level, accessible areas encourages gully development. The problem of grazing these lands properly is further aggravated by the varying period of plant development due to elevation and exposure. Because

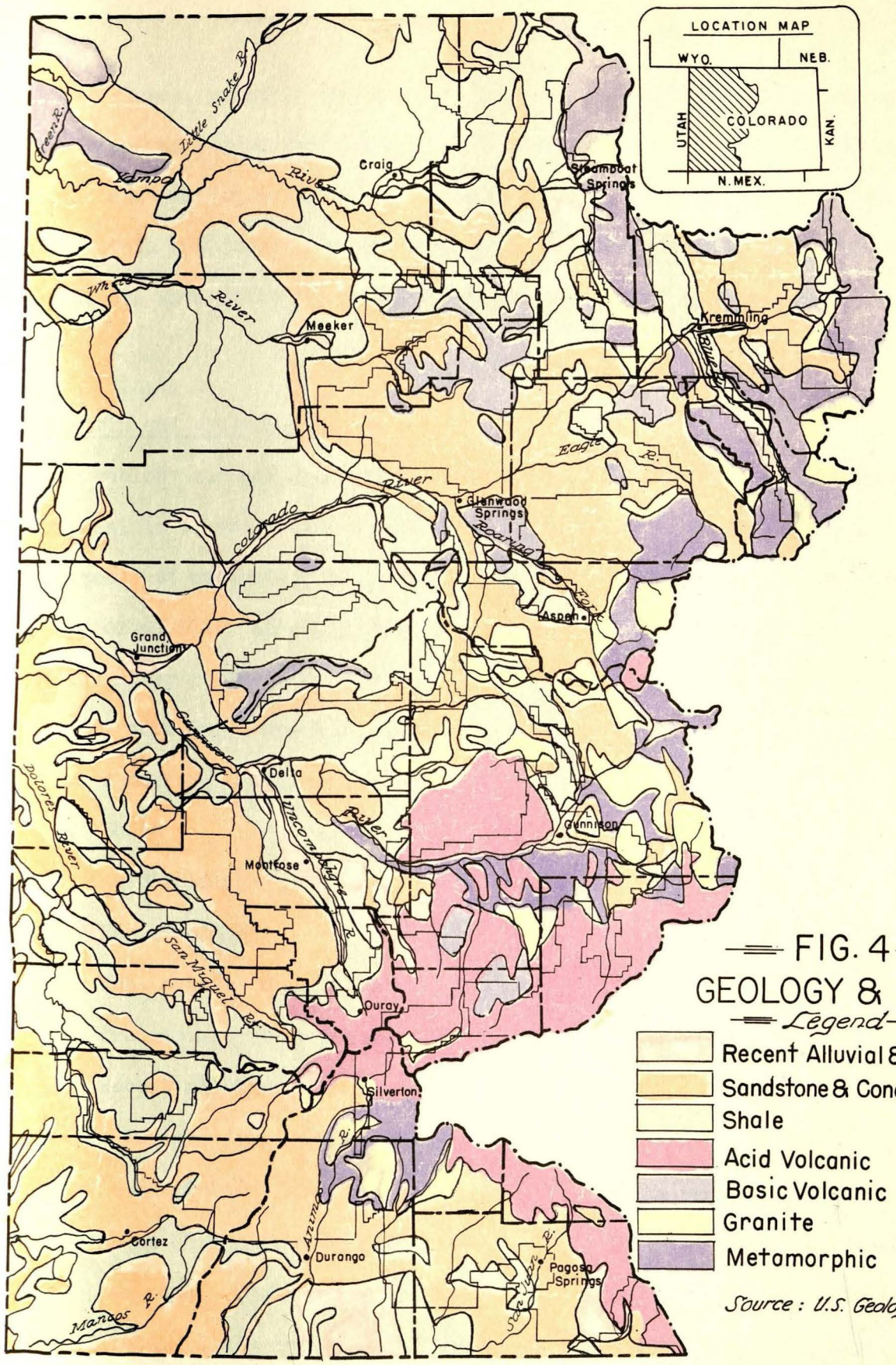

FIG. 4

GEOLOGY & SOILS

Legend

- Recent Alluvial & Glacial Deposits
- Sandstone & Conglomerate
- Shale
- Acid Volcanic
- Basic Volcanic
- Granite
- Metamorphic

Source : U.S. Geological Survey

of steep slopes, unstable soils, and a sparse cover of vegetation, cloudburst storms cause damage to farmlands and improvements, as well as severe loss of topsoil, and sedimentation of stream channels and reservoirs. Although slopes within the lower zone are more gentle than those at higher elevations, soils absorb water slowly and runoff is usually laden with silt.

Geology and Soils

Soil origin and characteristics

The geology and soils of the Western Slope are complex. Nevertheless, it is possible to group rock formations having similar characteristics for purposes of evaluating their water-yielding capabilities and the fertility and erodibility of soils derived from them. The following groups are based primarily on the mineral composition of the rocks, and secondarily on factors that influence soil-water relationships. (fig. 4)

1. Sandstone and conglomerates
2. Shale
3. Acid volcanic
4. Basic volcanic
5. Metamorphic (chiefly schist and gneiss)
6. Granite and other coarse-grained acid igneous rocks
7. Recent alluvium, terrace and glacial deposits

Soils derived from sedimentary rocks are by far the most extensive, especially in the intermediate and lower zones. Sandstones and conglomerates comprise about 40 per cent of the intermediate and lower zones, and one-third of the upper zone. These rocks are porous and constitute the main water-bearing strata. Sandy and gravelly soils are developed from them, and their ability to store water is relatively low. When protected by an adequate

vegetative cover, these coarse-textured soils have high water-absorption capacities. However, they erode readily where the plant cover is sparse. In the upper zone, these soils are usually low in fertility because of excessive leaching, while at lower elevations they are moderately fertile.

Shales occur mainly in the intermediate and lower zones and occupy more than one-third of the entire area. These rocks are slowly pervious to water, are subject to rapid weathering, and generally produce unstable soils. The fine-textured soils derived from shales absorb moisture slowly and yield large quantities of surface runoff. Consequently, much of the precipitation is ineffective for plant growth. These soils are usually rich in plant nutrients, and are productive in the upper zone where excess salts have been leached away.

Acid volcanic rocks occur mainly in the upper zone where they comprise about 15 per cent of the area. These fine-crystalline, light-weight, and light-colored rocks give rise to fine-textured soils of medium fertility and moderate erodibility. Such soils have a good capacity to store water, and when protected by vegetation they absorb water readily.

Granites and other coarse-grained, acid-igneous rocks occur sparingly and mainly in the upper zone. They produce coarse-textured, well-drained soils of low fertility and high erodibility.

Basic volcanic rocks are confined almost entirely to the upper zone, where they comprise 5 per cent of the area. They give rise to fertile, deep, black soils which are highly resistant to erosion when protected by vegetation. Representative of the most stable and most productive soils in the region, they have excellent moisture relationships, are capable of withstanding considerable abuse, and respond with a quick vegetative growth under conservative use.

Metamorphic rocks occur mainly along the Continental Divide of the upper zone. These rocks are resistant to weathering and produce soils of low erodibility and moderate fertility. Most of the soils are well drained and are capable of absorbing water rapidly.

Alluvium, terrace, and glacial deposits are found along stream bottoms and drainageways. Soils developed from these materials are well drained, fertile, and have a high moisture-intake capacity. Most of the cultivated land occurs on alluvium and terrace deposits. The glacial deposits at higher elevations give rise to porous, rocky soils. Because of their high water-absorption rates and moisture-holding capacities, such deposits are excellent watershed lands.

Erosion

Soil erosion is responsible, directly or indirectly, for most of the critical problems of land use. Specifically, erosion has affected the social and economic welfare of the people by; (1) lowering soil fertility and water-absorbing capacity, thereby reducing forage and crop yields; (2) imparing the quality of water for irrigation and other purposes; and (3) silting of reservoirs and damage to other urban and rural developments and improvements. The relative magnitude of the erosion problem in each elevational zone is discussed below.

Upper zone.--Soils of this zone are comparatively free from accelerated erosion. They are generally stable and are capable of withstanding considerable abuse. Partly because of their fertility and high moisture-absorbing capacity, they support a denser plant cover than those at lower elevations. Furthermore, the climate of this zone is not especially conducive to erosion. Melting of snow, though often contributing to spring floods, produces accelerated erosion only on seriously depleted sites. Torrential summer storms

rarely occur at high elevations. Accelerated erosion in the upper zone appears to be most common in depleted grassland parks and openings in timber and brush where livestock tend to congregate. It is probably the most serious on the Uncompahgre, San Juan, and Grand Mesa National Forests at the present time.

Intermediate zone.---About two-thirds of the area within the intermediate zone is eroding severely. Sheet and gully erosion are especially serious on pinon-juniper lands. Where topsoil has washed away, the subsoil is exposed and erosion pavement covers the ground between the pedestalled trees. Grazing use has reduced the amount of litter and herbaceous growth. Except under tree crowns, most of the precipitation runs off, carrying large quantities of soil and reducing the productivity of the site. The most critical erosion conditions are found where the pinon-juniper type occurs on soils derived from shale, especially in association with steep slopes.

Erosion in the sagebrush type is nearly as severe as that on pinon-juniper lands. Sagebrush occurs more commonly in the valleys and on benches and terraces where the soil is generally deep and productive, whereas the pinon-juniper type occupies the steeper slopes and shallow soils. Severe sheet erosion occurs on bare areas between sagebrush plants. As much as two feet of soil has been removed in many places. Gullies continue to grow and contribute large quantities of sediment to streams. Erosion is most prevalent on soils derived from Mancos and Wasatch shales. On these soils effective precipitation is inadequate to leach away the excess salts, and, as a result, both plant growth and water-absorption capacity are reduced. Soils supporting stands of pinon-juniper and sagebrush with little other

herbaceous growth absorb water about one-fourth as fast as those where a desirable plant cover is present. In certain localities water intake is so low that nearly all precipitation runs off the land.

Cover afforded by shrubby plants within the mountain-brush type is dense enough to break the force of raindrops during cloudburst storms and thus reduce their beating action on the soil. Organic matter from falling leaves and decaying roots maintains soil stability, water intake, and fertility. Although soil erosion is evident in many localities, it is seldom severe. The mountain-brush type is a good watershed cover from the standpoint of soil stability.

Erosion on croplands, which comprise only 5 per cent of the zone, is often severe. However, the total quantity of sediment contributed from those lands is minor in amount compared with that from range lands. Present irrigation methods, particularly the volume of water applied and disposal of waste water, cause accelerated erosion on many irrigated farms. Erosion is generally more serious on the steeper dry-farmed areas. Spring droughts and high winds in southwestern counties has caused considerable soil loss on bean lands in recent years. No crop residue is left to stop the soil from blowing after the beans are harvested.

Lower zone.--Most of the land in the lower zone is eroding severely. Critical conditions are found in pinon-juniper, sagebrush, greasewood, and desert-shrub types where the vegetation offers even less protection to the soil than in the intermediate zone. Soils are commonly fine-textured, highly alkaline, and absorb water slowly. Geologic erosion has created badlands on shale deposits. Erosion on irrigated lands, which comprise about one-tenth of the zone, appears to be less severe than in the intermediate zone.

Sediment

Damage caused by sediment is often greater than that caused directly

by erosion. Among the immediate damages are the impairment of irrigation systems, including sedimentation of reservoirs, canals, and stream channels; damage to agricultural crops, farm lands, and transportation systems; and impairment of recreation and wildlife values.

Recent estimates indicate that the dead storage of Lake Mead is one-fifth filled. Including bedload deposits, it is estimated that the storage capacity is being reduced by about 100,000 acre-feet annually. An indication of the suspended sediment contribution from the Western Slope is given in Table 3.

Table 3.--Annual suspended sediment contributed by tributaries to Lake Mead

Drainage	Station	Drainage area	Colorado portion	Sediment1/	Sediment per sq. mi.
		sq.mi.	per cent	acre-feet.	acre-feet
Colorado R.	Cisco, Utah	24,100	98	11,800	0.49
San Juan R.	Bluff, Utah	23,900	25	28,400	1.19
Green R.	Green River, Utah	40,600	22	15,800	0.39
Total or average		88,600	43	56,000	0.63

1/ Converted from tons on basis of 75 lbs. per cu. ft. of dry deposit

The combined annual sediment load for the three stations listed above is 37 per cent of the quantity reaching Lake Mead. The San Juan River is the principal contributor of sediment to the Colorado River above Lee's Ferry, Arizona. It contributes nearly two and one-half times as much silt as the main Colorado at Cisco, Utah. One-fourth of its drainage lies in Colorado. The Green River above Green River, Utah, yields the least suspended sediment per unit of watershed area of the three major drainages. Sediment measured at Cisco, Utah comes almost entirely from western Colorado and amounts to about 8 per cent of the suspended load measured at Lake Mead. Of perhaps greater importance is the fact that the suspended sediment load at Cisco

has increased since 1915. (Table 4) The 1930-1942 data indicate a close relationship between acre-feet of annual runoff and acre-feet of sediment. On the basis of this correlation, the annual runoff experienced in the 1914-1915 period under present watershed conditions would have yielded about 50 per cent more sediment.

Table 4.--Suspended sediment yield of the Colorado River

River	Station	Period	Drainage area	Average annual runoff	Average annual suspended sediment	
					Total	per sq. mi.
			sq. mi.	M ac.ft.	ac.ft.	ac.ft.
Colorado	Kremmling1/	1905-06	2,360	1,103	167	0.07
Colorado	Palisade	1905-06	8,790	3,558	950	0.11
Gunnison	Whitewater	1905-06	8,020	2,615	1,200	0.15
Colorado	2/	1905-06	16,810	6,172	2,150	0.13
Colorado	Cisco, Utah	1914-15	24,100	5,799	8,175	0.34
Colorado	Cisco, Utah	1930-42	24,100	5,152	3/10,425	0.43

1/ Below outlets of Muddy and Blue Rivers.
2/ Watershed area above Palisade and above Whitewater.
3/ Volume weight of 85 lbs. per cu. ft. of dry deposit used here for similar comparisons with early-period measurements.

The annual load of suspended material in the Colorado River is low near its headwaters. The more distant downstream, the more the load increases. This difference substantiates results of erosion surveys and observations that accelerated erosion is active on the downstream areas, and that minor soil losses are occurring in the high-mountain watersheds.

About 60 per cent of the annual sediment load is transported in April and May and streambank cutting during this period is the major source. Small quantities of sediment are transported during June and July. Almost 30 per cent of the yearly load measured at Cisco, Utah during a 3-year period was produced from August to October, inclusive. High-intensity storms during the latter

part of the growing season on pinon-juniper, sagebrush, and desert-shrub lands probably account for much of this sediment.

The foregoing discussion refers only to the material carried in suspension. In addition, there is a considerable amount of coarser material, commonly termed bedload, which is rolled along the stream bottoms. No records of the quantity of this material are available, but estimates of bedload materials in streams of other localities have varied from 25 to 100 per cent of that carried in suspension.

Climate and Stream Flow

Climate

The climate of western Colorado is fairly typical of that in the intermountain province. At low elevations annual precipitation seldom exceeds 10 inches, the growing season is long, and winters are comparatively mild. At high elevations precipitation may exceed 30 inches, summers are short, and winters severe. Between these extremes local climate varies with elevation and exposure. (Fig. 5).

The pattern of seasonal precipitation and temperature is similar at all elevations. About 60 per cent of the precipitation is received from March through September, but very little normally occurs during the month of June. July and August are the hottest months, and January and February are the coldest.

The climate of the lower zone permits diversified farming and some winter grazing. Irrigation is needed to grow crops. Precipitation averages less than 14 inches annually, with about one-third in the form of snow. While precipitation is unimportant as a source of stream flow, it is

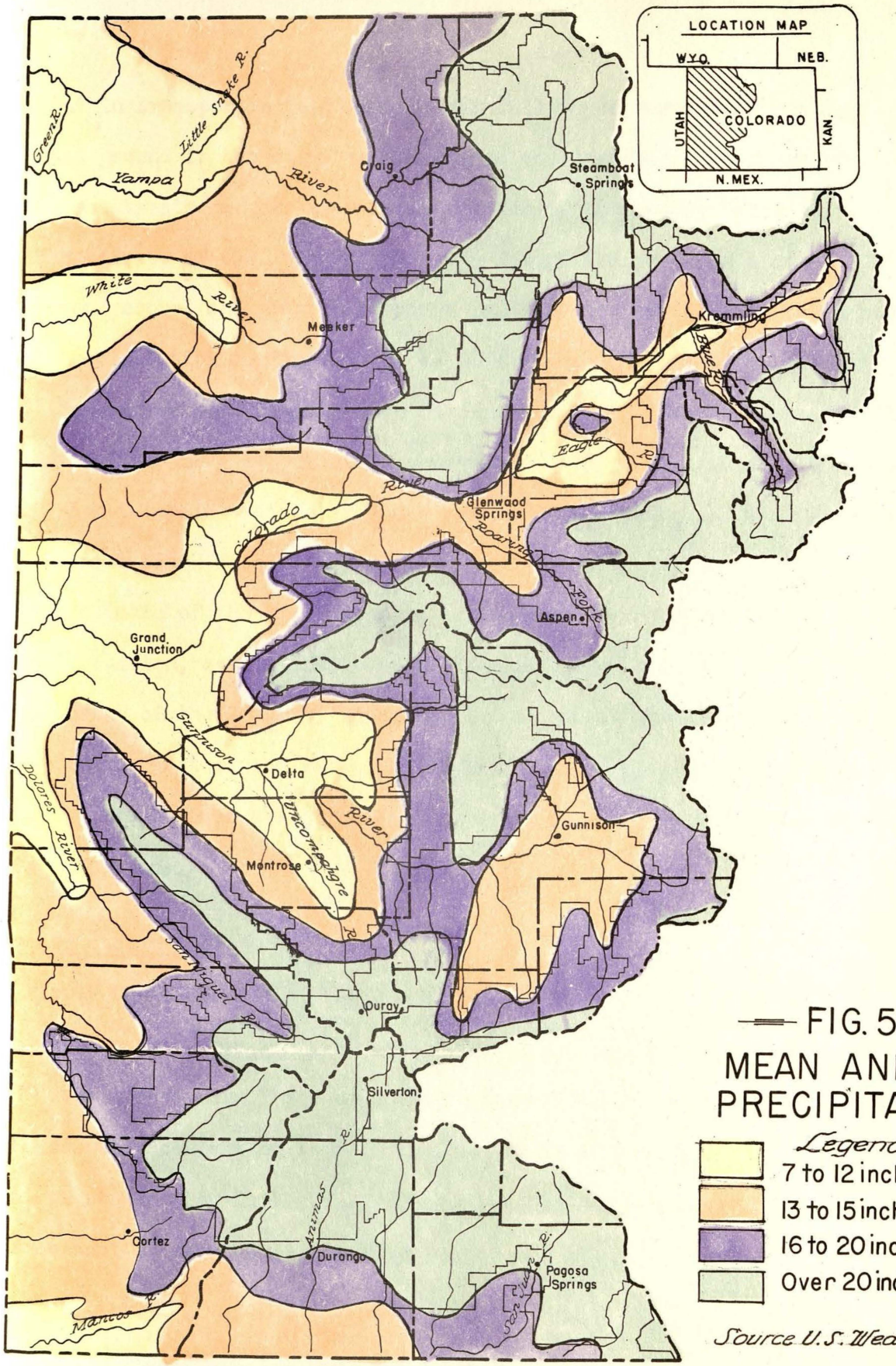

FIG. 5

MEAN ANNUAL PRECIPITATION

Legend

- 7 to 12 inches.
- 13 to 15 inches.
- 16 to 20 inches.
- Over 20 inches.

Source U.S. Weather Bureau

important in transporting sediment. Rain falling on snow and sparsely vegetated ground in the early spring causes considerable runoff and erosion. High-intensity storms make up a large portion of the summer rainfall.

The climate of the intermediate zone favors the production of hay, a few dryland crops, and grazing of range lands during spring and fall months. Annual precipitation varies from 14 to 20 inches, nearly half of which is snow. Snow melts more rapidly than in the upper zone and often causes soil movement. It is more important as a source of stream flow than in the lower zone. High-intensity rain storms are prevalent during August and September, often causing flash floods.

The climate of the upper zone is conducive to water yield, timber and forage production, and is ideal for recreation during summer months. About three-fourths of the 20 to 35 inches of annual precipitation occurs as snow which provides most of the water for stream flow. Rain storms are of low intensity except where abrupt changes in altitude occur within a few miles of the lower zone.

Source of stream flow

Nearly three-fourths of the annual stream flow from western Colorado originates in the upper zone, and over one-half comes from areas above 10,000 feet. Less than 5 per cent of the flow originates in the lower zone. Depth and water content of snow in the high mountains largely determine the amount of stream flow during the following summer. The average depth and water content of snow at different elevations on April 1 are given below:

Elevation (Feet)	Snow depth (Inches)	Water content (Inches)
7,000 - 8,000	21	8
8,000 - 9,000	38	11
9,000- 10,000	45	14
10,000- 11,000	56	18

Very little snow remains below 7,000 feet on April 1. Snowfall in the lower zone is light, and much of it is lost through evaporation.

Characteristics of stream flow

All streams originating in western Colorado have similar characteristics of flow. Over one-half of the annual stream flow of the major streams occurs during May and June due to melting of snow. It drops rapidly in July and decreases steadily in August and September. These months account for only one-fifth of the annual flow. Only a small portion of the total annual flow occurs during the critical late-summer and fall irrigation season. Stream flow decreases gradually throughout the fall and winter, reaching a minimum just before snow-melt starts again.

Water yield and use

An average of over 12 million acre-feet of water originates annually on the Western Slope of Colorado. Only 10 per cent of this supply is used in Colorado. The remainder comprises over three-fourths of the stream flow presently measured at Lee's Ferry, Arizona. A summary of the annual water resources and depletions by major drainages is given in Table 5.

Table 5.--Present division of water originating in western Colorado (thousand acre-feet)

Drainage	Water produced	Used in Colorado		Water leaving State
		Western Slope	Eastern Slope	
Green, Yampa, and White R.	2,221	115	0	2,106
Colorado R. above Gunnison R.	4,282	376	96	3,810
Gunnison R.	2,477	335	2	2,140
Dolores R.	679	65	0	614
San Juan R.	2,605	238	4	2,363
Total	12,264	1,129	102	11,033

The average market value for irrigation water in the Basin is estimated at $1.50 per acre-foot. On this basis, water originating on the Western Slope is worth over 18 million dollars annually for irrigation purposes alone. Annual water yield from the upper zone is about 1½ acre-feet per acre; at $1.50 an acre-foot, this amounts to $2.25 per acre. Capitalization of the $2.25 at 5 per cent is $45 per acre of watershed. Investments in irrigation, water power, and flood control increase the watershed value of the land in the upper zone to nearly $75 per acre.

According to the Upper Colorado River Basin Compact negotiated at Vernal, Utah, on July 21, 1948, Colorado is allotted 51.75 per cent of the apportioned flow measured at Lee's Ferry. In normal years, this amount appears adequate to meet demands of potential projects as outlined by the Bureau of Reclamation (32). This report indicates that the Western Slope can consume annually another 1 million acre-feet of water, and that the Eastern Slope might receive an additional 2 million acre-feet. When beneficial use of the water resource is fully realized, the limited supply will doubtless become more apparent.

Almost two-thirds of the irrigable acreage in western Colorado is now receiving water (Table 6). About half of the potential irrigable cropland lies in the Yampa and White River drainages. Knowledge of the location and amount of hay and pasture land suitable for irrigation is limited, but the Bureau of Reclamation estimates that an additional 500,000 acre-feet of water can be used annually in the Upper Basin for this purpose alone.

Table 6.-- Present and potential acreage of irrigated land in western Colorado (thousand acres)

Drainage	Irrigated land	New irrigable land	Total irrigable land
Green, Yampa, and White R.	106	198	304
Colorado R. above Gunnison R.	256	50	306
Gunnison R.	238	62	300
Dolores R.	38	57	95
San Juan R.	132	111	243
Total	770	478	1,248

The use of water for irrigation increases from north to south. The minimum use is in the Green River drainage where slightly more than 1 acre-foot per acre is applied annually. Maximum use is in the San Juan basin where about 1.8 acre-feet per acre are consumed. The average amount of water applied for irrigation is about 1.5 acre-feet per acre, which is not considered excessive for the type of crops grown.

In localities where native hay is the main crop, the common practice is to irrigate heavily until the hay is cut. Natural drainage is usually adequate to prevent water-logging of soils and much of the water returns to the streams as seepage. This method results in use of more water than

needed, and it is doubtful that maximum production of high-quality hay is obtained.

A study of potential domestic and industrial needs for water has not been made. It is expected that these needs, along with those for hydroelectric power, will increase. Although topography of western Colorado is conducive to the development of water power, the number of sites suitable for dams is limited. During dry years, the demand for water in late summer and fall may result in conflict between industrial and agricultural interests. Dams for flood control add further to the problem of water development and use.

Floods

Floods are of three types: (1) those due to general rains of several days' duration over large areas; (2) those caused by high-intensity cloudbursts of short duration covering small areas; and (3) those from melting of snow during spring months.

Floods due to prolonged general rains are relatively infrequent. There have been four periods of such rains during the past 40 years. Rainfall ranged from 2 to 8 inches with the maximum recorded in the San Juan mountains.

Rates of precipitation during cloudburst storms are so high that most of the water runs off the land and causes flash floods. Because of their localized nature the total stream flow is not great and damage per storm is much less than that caused by the first type. However, they occur frequently and are the principal source of flood damages, particularly to railroads, highways, roads, and bridges. Cloudbursts are most common between 6,000 and 7,000 feet along the western foothills where the warm air drifts upward toward the mountains and is cooled rapidly.

High water during the snowmelt period occurs with regularity each spring. The years of abnormally heavy precipitation during the winter and early spring months, the accumulation of snow represents enormous volumes of water. Since the bulk of this water is released during a 30- to 60-day period, spring flooding is inevitable. Other factors responsible for spring floods are rapid melting of snow due to unseasonably warm weather, and warm rains occurring during the snowmelt period.

Estimated annual flood damages in the major drainage basins are shown in Table 7. Direct damages in the three drainages average $396,000 annually, based on areas adjacent to the major streams. When damage along tributaries is included, the total damage may reach $500,000 each year. The main flood damage areas are along the Animas, La Plata, San Juan, Los Pinos, and Mancos Rivers in the San Juan basin.

Table 7.—Average annual flood damages by principal drainages (thousand dollars)

Kind of damage	White and Yampa R.	Colorado R.	San Juan R.
Crops, lands, and irrigation works	82.0	73.3	115.0
Urban	1.5	10.7	6.0
Transportation and utility	1.4	53.9	14.6
Unclassified	0.1	36.8	0.8
Total	85.0	174.7	136.4

Biologic Relations

Native Vegetation

Native plant cover consists of eleven principal types (Fig. 6). The character, extent, and location of these types greatly influence the

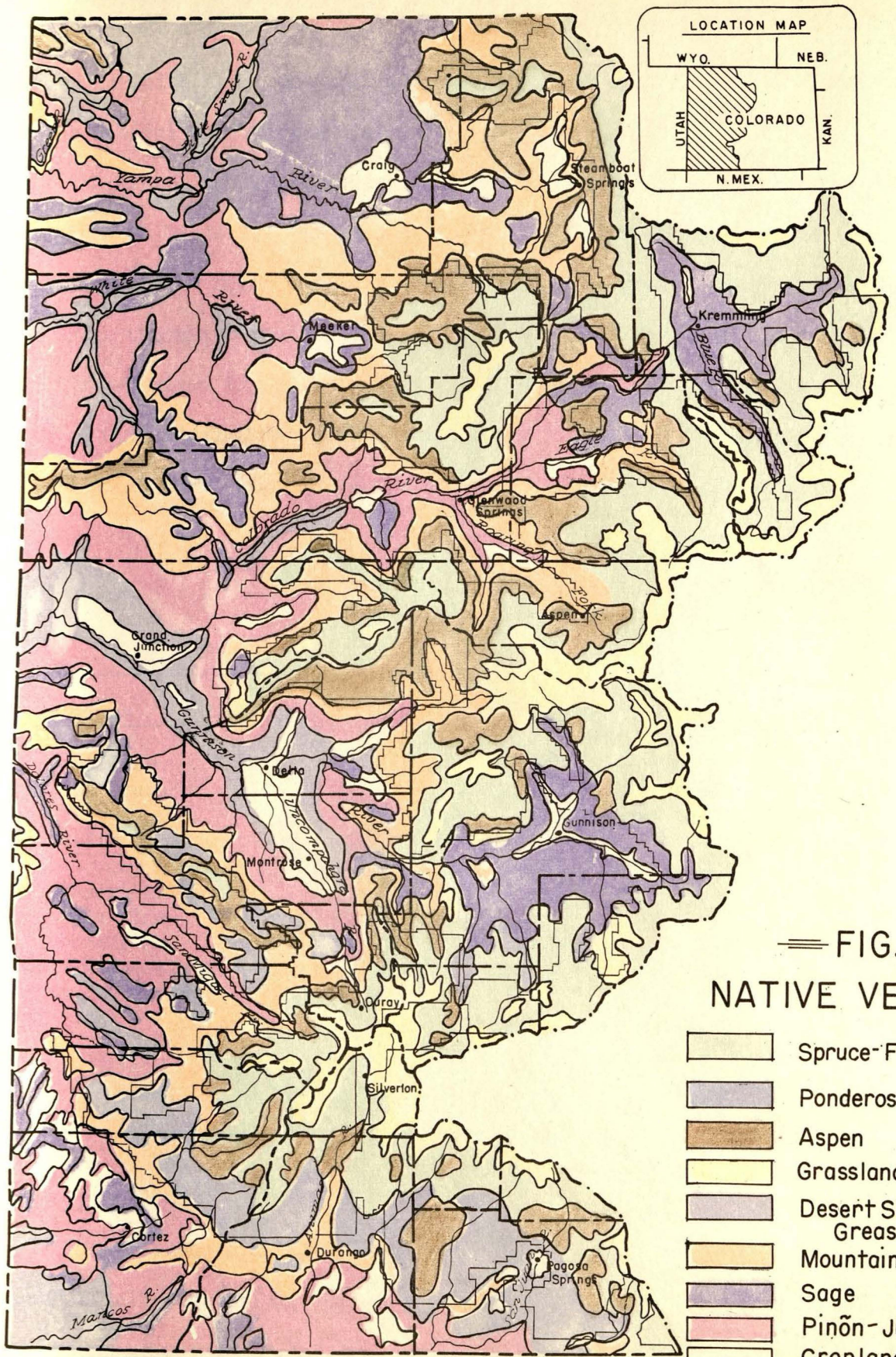

FIG. 6

NATIVE VEGETATION

- Spruce-Fir & Lodgepole Pine
- Ponderosa Pine
- Aspen
- Grassland & Barren
- Desert Shrub & Greasewood
- Mountain Brush
- Sage
- Pinõn-Juniper
- Cropland

Source: U.S. Geological Survey. U.S. Forest Service

manner in which they are used by man, and this use, in turn, is reflected in the present condition of the soil and plant cover.

The extent and location of vegetation types by elevational zones are given in Table 8. Spruce-fir, aspen, and mountain-brush types are most extensive in the upper zone. In the intermediate zone, pinon-juniper and sagebrush types are predominant, while at low elevations the salt-desert-shrub and pinon-juniper types are almost equally extensive. The following description of individual types points out how the character, condition, and use of the plant cover lead to specific problems in land management.

Table 8.--Approximate extent and distribution of major vegetation types in western Colorado (thousands of acres)

Type	Zone			Total
	Upper	Intermediate	Lower	
Pinon-juniper	0	4,115	1,188	5,303
Mountain brush	1,635	2,212	0	3,847
Sagebrush	986	1,868	265	3,119
Spruce-fir	2,856	0	0	2,856
Aspen	2,463	200	0	2,663
Salt-desert shrub	0	0	1,348	1,348
Lodgepole pine	1,200	0	0	1,200
Ponderosa pine	710	400	0	1,110
Mountain grassland	779	0	0	779
Alpine grassland	402	0	0	402
Greasewood	0	0	128	128
Total	11,031	8,795	2,929	22,755

Alpine grassland

This treeless type varies from precipitous rocky wastes, practically devoid of all vegetation, to grassy alpine meadows. It occupies less than 2 per cent of western Colorado. The most extensive areas occur in the east central portion along the continental divide and in the San Juan mountains.

It is important chiefly from the standpoint of water yield and recreation, although some of the more extensive areas are grazed by sheep during a short period in the summer.

Sedges, grasses, mosses, dwarf willows, and colorful weeds compose the characteristic vegetation. In general, the turf-forming vegetation provides a stable cover for the thin rocky soils. When this protective turf is broken by excessive grazing and trampling by sheep, erosion becomes a problem and is accentuated by the precipitous slopes and heavy snowfall common to the type.

Costello and Schwan (4a) have made a preliminary report on range conditions, trends, and land use in the alpine type.

Spruce-fir and lodgepole pine type

These types together occupy about 16 per cent of the total area of western Colorado. They contain the bulk of the commercial timber and are highly important for water yield.

Lodgepole pine occurs mainly in the northeastern portion at elevations of 8,000 to 11,000 feet. It commonly occupies the drier sites or those formerly occupied by spruce and fir that have been burned over. The type consists of varying stands of mature and immature lodgepole pine interspersed with open parks. Young stands are generally overstocked and are frequently stagnated. Mature trees are seldom larger than 2 feet in diameter. Little herbaceous growth occurs in the understory, and the type has little value for grazing.

The spruce-fir type occurs at similar elevations on the slopes of the main continental divide, the San Juan and West Elk Mountains, and also on

the plateaus and mesas farther west. The White River Plateau and Grand Mesa support extensive stands of spruce and fir. The type is characterized by dense stands of overmature Engelmann spruce and alpine fir, among which are small parks and meadows. A recent epidemic of bark beetles, centered on the White River National Forest, has killed much of the spruce timber. Grazing of livestock within the type is limited mainly to the open areas.

Aspen type

This type occurs in the lower portion of the lodgepole pine and spruce-fir belt, and is characterized by aspen in pure stands or intermixed with conifers. It is well distributed throughout the mountain section of western Colorado and occupies nearly 11 per cent of the area. The type is often found on coniferous-timber sites that have been burned over and appears to be invading grassland parks in many areas. It is found on a variety of soils, about three-fourths of which are of sedimentary origin. Although these soils tend to be erosive, the protective cover of the trees and the heavy leaf mulch they provide each year are effective in holding the soil in place. The aspen type is highly valuable as watershed cover as well as for summer grazing of cattle, sheep, and big game. Aspen has limited commercial value because of its small size, crooked bole, and other inferior qualities.

Open stands of aspen that have been subjected to moderate grazing use generally support an excellent cover of grasses, forbs, and shrubs in a well-balanced mixture. Where grazing has been excessive the more desirable grasses and forbs have given way to less palatable or noxious plants such as needlegrass, hairy goldaster, tarweed, and sneezeweed. Rarely, however, is the herbaceous understory absent. In certain areas bluegrass has become dominant,

probably as a result of close grazing use. Bluegrass, although highly palatable to livestock, produces only a limited amount of herbage, and its growth is undependable in dry years.

Although poisonous plants are not confined to the aspen type, the two most important ones, larkspur and sneezeweed, are quite common there. Cattle losses from larkspur sometimes amount to 5 per cent on heavily infested areas. Numerous areas infested with low larkspur cannot safely be grazed until the plant has withered.

A survey made in 1938 showed that sneezeweed occurs on 1½ million acres of rangeland in Colorado. The worst infestations are on the White River, Grand Mesa, and Uncompahgre National Forests. It is poisonous to sheep and is estimated to cause losses as high as 10 per cent to some bands grazing infested ranges. Doran and Cassady (6) have found that losses from this plant can be greatly reduced by proper sheep management. Nevertheless, losses continue to occur in the region, and it appears that sneezeweed is spreading on rangelands that are heavily utilized.

Mountain grassland type

This type occurs in parks scattered through the spruce-fir, lodgepole pine, and aspen types. It comprises about 4 per cent of the total area of western Colorado. Some of the largest grassland parks occur on the White River National Forest, where Thurber fescue is dominant on the better ranges. Various stages of depletion are represented. Some parks support mainly needlegrass, sheep fescue, brome, wheatgrass, geranium, yarrow, sneezeweed, dandelion, and showy goldeneye. Other parks are characterized by bluegrass. Extensive grasslands also occur on the Grand Mesa and Gunnison National Forests. On the Grand Mesa, areas that once supported

Thurber fescue have deteriorated to weed types, dominated by sneezeweed and lupine. Pocket gophers are abundant and apparently destructive to the range. Many parks on the Gunnison National Forest support stands of Thurber fescue in various stages of deterioration. On the Uncompahgre plateau hairy goldaster dominates many openings among the trees. This herb is practically worthless for grazing. On the Routt National Forest, red and sheep fescues and narrow-leaf sedges are common in the grassland types of the lodgepole pine belt. However, needlegrass and tarweed are about the only plants found in heavily grazed areas.

This type is much more important for grazing and watershed protection than its size would indicate. The parks are the natural congregating areas for livestock and represent key areas in the management of most summer ranges.

Ponderosa pine type

Comprising about 4 per cent of western Colorado, the ponderosa pine type is valuable for timber production, watershed protection, and grazing. It occurs most extensively in the southwestern part of the territory and is found as far north as the Gunnison River drainage and the Uncompahgre Plateau. Most of the type occurs on sedimentary formations; about three-fourths of the soils are derived from sandstones and the remainder from shales. It is subject to high-intensity summer storms, and the danger of erosion is great when the soil is exposed. The most accessible timber has been cut, but reproduction in cut-over areas is generally ample for restocking. Exceptions occur where repeated burning has followed logging. Scrub oak and sagebrush dominate those sites, and only scattered pines remain. Buried

charred stumps testify to the former presence of ponderosa pine in extensive areas of the mountain brush type in southwestern Colorado.

Douglas fir is frequently associated with ponderosa pine, occupying the north exposures and cooler sites, especially at the higher elevations.

Arizona fescue and mountain muhly are considered the climax grasses of the ground flora, but in much of southwestern Colorado they have been replaced by blue grama and threadleaf sedge on the drier sites, or by Kentucky bluegrass in the moist valleys along streams. Hairy goldaster, fringed sagebrush, and Fendler sandwort are present in considerable quantity throughout the type. The abundance of these inferior plants indicate that abuse of ponderosa pine rangelands has greatly reduced the grazing value of the type. Costello and Schwan (4) have developed criteria for judging range condition and trends in the ponderosa pine type, although they apply only indirectly to Western Slope conditions.

Mountain-brush type

The mountain-brush type represents a transition between the moist, forested areas above 8,000 feet and the more xeric types of vegetation below 6,500 feet. In addition to its association with ponderosa pine, it occupies about 15 per cent of western Colorado. It is highly valuable for watershed protection and is used extensively for late spring and fall pasture.

The composition of the type varies greatly. Scrub oak may occur in nearly pure stands or mixed with serviceberry, snowberry, chokecherry, sagebrush, and rabbitbrush. In certain localities the oak is almost absent. The understory is commonly composed of various bluegrasses,

wheatgrass, sedges, and weeds. Dandelion frequently dominates heavily grazed parks within the type.

Evidence of range deterioration is not uncommon in the mountain-brush type. Undoubtedly many areas are used earlier in the spring than the forage plants can withstand. Though much of the type is used as spring range, it appears to be better adapted to summer grazing. Sites are drier and slopes are often steeper than at higher elevations. Use of steep and highly erodible slopes has resulted in unsatisfactory watershed conditions in local areas. Scrub oak presents a definite problem in the management of brush ranges. Many areas that formerly produced abundant forage now are occupied by impenetrable thickets, apparently as the result of livestock grazing, logging, and perhaps fire control. This has reduced the grazing capacity of the range and resulted in overgrazing of the more accessible areas.

Pinon-juniper type

Occupying one-fifth of western Colorado, this type provides forage for big game during the winter, as well as spring-fall and winter range for livestock. Most of the land is under the jurisdiction of the Bureau of Land Management. Erosion is severe and widespread. Soils are derived mainly from sandstone, but shale soils are also extensive. Plant growth is limited by available soil moisture; annual precipitation amounts to less than 10 inches in some localities and seldom exceeds 18 inches.

The type reaches its best development on the higher slopes where climatic conditions and herbaceous plants are similar to those of the mountain-brush type. At lower altitudes it consists of relatively open stands of juniper, modified here and there by sagebrush parks. At its lower

limit it commonly blends into the salt-desert shrub type.

Herbaceous vegetation is very sparse throughout most of the type, and many of the plants remaining are of little value for grazing. Browse plants such as serviceberry, mountain mahogany, snowberry, and bitterbrush are often hedged closely, and in some localities they have been destroyed by livestock and big game. The degree of cropping of juniper often provides a measure of deer concentration, as in many areas it is about the only forage left for deer use.

Water for livestock is scarce except during winter or early spring. Much of the type is poorly adapted to grazing because of steep slopes and cliffs. Regardless of these conditions, and the fact that most of the type supports so little palatable forage as to be practically valueless for grazing, it appears that these lands are being grazed too closely and too soon after plant growth begins to maintain or restore desirable range-watershed conditions.

Sagebrush type

This type occupies about 13 per cent of the territory. It occurs in isolated blocks throughout the region on deep, well-drained soils. It has a wider elevational range than any other type. About 60 per cent of the type occurs in the intermediate zone, 32 per cent in the upper zone, and 8 per cent in the lower zone.

Most sagebrush land is used for grazing. Big sagebrush is usually dominant in the type, although black sage is common on shallow, rocky soils, and silver sage occurs on moist sites at higher elevations. Rabbitbrush, serviceberry, bitterbrush, cliff rose, prickly pear, and many kinds of

grass and weeds are associated with it.

Where annual precipitation is less than 15 inches, the herbaceous plant cover is generally depleted. Areas having a more favorable moisture supply are in somewhat better condition. The problem of improving depleted portions of the type is important because of active soil erosion and the need during spring months for more forage, which this type is capable of producing.

Salt-desert shrub type

This type occupies semi-desert lands where soils are high in salt content. It comprises only 5 per cent of the Western Slope and has little value except for limited winter grazing by sheep. It occurs most extensively in the Uncompahgre and lower Colorado River valleys, and along the Wyoming border in Moffat county.

Practically all the soils are derived from shale. Heavy clay soils, especially those derived from Mancos shale, support widely-spaced plants of mat saltbush. Areas with alluvium over the more impervious shale substrata have moderately dense stands of shadscale, rabbitbrush, snakeweed, winterfat, and prickly pear. The more common grasses include galleta, Indian ricegrass, and several kinds of wheatgrass.

Although the type receives less than 10 inches of precipitation annually, erosion is widespread and severe, especially during high-intensity storms. It has suffered greatly from overgrazing in the past, and is most susceptible to invasion by halogeton, a poisonous plant that is spreading rapidly on similar sites in Utah, Nevada and Idaho.

Greasewood type

The greasewood type is similar to the salt-desert shrub type and is

commonly associated with it along valley bottoms that are either subject to periodic flooding or underlain with ground water at shallow depths. Soils are highly impregnated with salts. Greasewood is the dominant plant in the type, associated with desert shrubs, rabbitbrush, alkali sacaton, foxtail, salt grass, sand dropseed and other alkali-tolerant species. The type is of minor importance as it occupies a small area and is capable of producing little forage.

The Forage Resource

Extent and character

Forage-producing lands, including range land, hay land, and irrigated pasture, occupy nearly 18 million acres. Rangeland produces about 42 per cent of the annual forage supply on 17 million acres, while hay land and irrigated pastures produce the remainder on less than 1 million acres. Most rangeland supplies far less forage than it is capable of producing.

The relative importance of the various types of vegetation in supplying forage is shown in Table 9. The approximate acreage used for grazing is also shown to indicate the relative productivity of each type.

Table 9.--Source of annual forage supply in western Colorado.

Type	Forage produced		Area occupied	
	Animal-unit-months (thousands)	Per cent of total	Acres (thousands)	Per cent of total
Hay	1/2,409	48.8	409	2.3
Irrigated pasture	486	9.8	243	1.4
Aspen	480	9.7	2,400	13.6
Mountain brush	405	8.2	3,400	19.2
Sagebrush	307	6.2	2,932	16.6
Mountain grassland	257	5.2	770	4.4
Pinon-juniper	230	4.6	4,860	27.5
Ponderosa pine	167	3.4	1,000	5.6
Alpine grassland	110	2.2	330	1.9
Salt-desert shrub	86	1.7	1,200	6.8
Greasewood	8	0.2	126	0.7
Total	4,945	100.0	17,670	100.0

Aspen and mountain-brush types are the most important producers of native forage, followed by sagebrush and mountain grassland types. Grassland and aspen types produce the most native forage per acre. They supply

1/ Total production of hay in 1949, converted to animal unit months on the basis of 600 pounds per animal unit month.

about 17 per cent of the annual forage crop and occupy 20 per cent of the forage producing area. The pinon-juniper type, on the other hand, produces less than 5 per cent of the forage on 27 per cent of the land.

Forage supplies available during different seasons of the year are not well balanced. (Table 10) Summer ranges provide forage for nearly 1.7 million AUM; spring-fall ranges provide 0.7 million; and winter ranges (including hayland) provide 2.5 million. Considering that summer ranges are used approximately 4 months, the monthly supply of forage amounts to 420,000 AUM. On spring-fall range, used approximately 3 months, the monthly supply is only 230,000 AUM. During the 5-month winter period 515,000 AUM feed, including hay, are available each month. Forage on winter ranges, exclusive of hay, amounts to only 167,000 AUM. These figures are related, in a general way, with range conditions and the ability of seasonal ranges to produce forage.

More than half the forage grazed during the summer is furnished by aspen, mountain-brush, and mountain grassland types. Sagebrush, pinon-juniper, and mountain-brush types supply nearly equal amounts of forage on spring-fall ranges. Forage on winter range land is produced principally by salt-desert shrub, pinon-juniper, and sagebrush types. However, these types produce only 7 per cent of the total feed available during winter months. Because local winter range is limited, cattle depend mainly on hay, and many sheep use desert ranges in eastern Utah and southern Wyoming.

Supply and demand

A comparison of available forage and feed supplies with livestock requirements indicates that they are nearly in balance on a year-long

basis. According to U. S. Census reports, there were 434,392 animal-units 6/ in western Colorado in 1950. These animals require 5,212,704 animal-unit-months' feed each year, compared with an estimated forage supply of 4,945,000 (Table 10). This represents a shortage of only 5 per cent. However, it does not give an accurate picture of seasonal forage supplies.

Range lands best adapted for spring-fall grazing furnish less than half the forage required at that time. Even if all irrigated pasture lands were used during these months, in addition to range land, the estimated forage supply would still be short of the demand. Part of the deficiency in the fall is met by using crop aftermath, but the shortage during spring months remains critical. Consequently, in many instances, livestock overuse spring ranges, and use summer ranges too early.

Forage supplies available during the summer amount to about 85 per cent of the livestock requirement. This includes the requirement of out-of-state sheep that consume an estimated 200,000 AUM forage 7/. However, it does not take into account the forage required by calves and lambs that are marketed in the fall and that are not included in census reports. Summer ranges supply most of the forage for these animals.

Winter-forage supplies appear to be more than adequate to maintain local livestock, assuming that hay is usable by both sheep and cattle. Actually, most sheep depend on range land for winter forage and are given very little supplemental feed except during severe storms. Reliable inform-

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6/ 188,764 mature cattle, 140,439 heifers and steers, and 42,160 calves were reported on April 1, 1950. Considering heifers and steers as two-thirds of an animal unit, and calves as one-third, this represents 296,771 animal-units for cattle alone. Mature sheep numbered 625,296 and lambs 125,617. Considering 5 mature sheep or 10 lambs as an animal unit, this represents 137,621 animal units for sheep alone.

7/ USDA Circular 624 estimates 1 million sheep-months' feed (200,000 AUM) are obtained in western Colorado by sheep from bordering states.

Table 10.--Source of forage for livestock during seasonal grazing periods.

Source	Estimated grazing capacity	Area occupied: Acres	Area occupied: Per cent of seasonal area	Forage produced: AUM	Forage produced: Per cent of seasonal supply
	Acres/AUM	Thousands		Thousands	
Winter Use					
Hay land	1/	409	12.4	2,409	93.6
Salt-desert shrub	14	1,200	36.5	86	3.3
Pinon-juniper	25	1,300	39.7	52	2.0
Sagebrush	12	250	7.6	21	0.8
Greasewood	15	126	3.8	8	0.3
Total		3,285	100.0	2,576	100.0
Spring-fall use					
Sagebrush	10	1,982	27.8	198	28.8
Pinon-juniper	20	3,560	50.0	178	25.8
Mountain brush	9	1,500	21.1	167	24.2
Irrigated pasture	0.5	73	1.1	146	21.2
Total		7,115	100.0	689	100.0
Summer Use					
Aspen	5	2,400	33.0	480	28.6
Irrigated pasture	0.5	170	2.3	340	20.2
Mountain grassland	3	770	10.6	257	15.4
Mountain brush	8	1,900	26.4	238	14.2
Ponderosa pine	6	1,000	13.8	167	9.9
Alpine grassland	3	330	4.6	110	6.5
Sagebrush	8	700	9.6	88	5.2
Total		7,270	100.0	1,680	100.0
Grand Total		17,670		4,945	

1/

ation on the number of Colorado sheep that use winter ranges outside the State is not available, but it is estimated at about 60 per cent. If 40 per cent of the sheep remain in western Colorado they would require at least 300,000 AUM forage. All local winter ranges produce only 167,000 AUM forage. Grazing-capacity estimates indicate that many winter ranges in the territory are severely overstocked 8/. Stocking rates of 2 or 3 acres per AUM are not uncommon on ranges that have an estimated capacity of 10 acres or more per AUM. Considering that most of the hay produced is fed to cattle, it appears that there is an excess of feed for cattle during winter months. Much of this hay is probably used to carry them through the early spring period.

A comparison of supply and demand for forage in various sections of western Colorado shows that the above general situation exists throughout the territory. A balance is more nearly reached in the Gunnison Valley, while the greatest discrepancy exists in the vicinity of the Uncompahgre Valley.

The forage requirement of big game is not considered in the above analysis. It is estimated that 240,000 deer and 36,000 elk obtained forage from Western Slope ranges in 1952. On a basis of 5 deer or 2 elk per animal unit, big game represent a total of 66,000 animal units. This is 15 per cent as much as for livestock. Where forage supplies are relatively abundant and diversified, as on summer ranges, there apparently is little competition between game and livestock. However, on spring-fall and winter ranges competition for available forage is keen.

8/ Based on Department of Justice compilations for hearings in Grand Junction in Dec. 1947 "Consolidated Bands of Utes" vs U.S. #45585..

The Timber Resource 9/

Nearly one-half of western Colorado is forested, considering both commercial and noncommercial stands. Most of the timber is located within national forests where the merchantable volume is estimated at over 22 billion board feet. Watershed values of the high-altitude forests often exceed their timber values.

Engelmann spruce is the most important commercial species. It contains an estimated volume of 13.6 billion board feet, or over 60 per cent of the total merchantable volume (Table 11). It is well represented in forests throughout the region, commonly associated with alpine fir.

Table 11.--Relative importance of timber species in western Colorado
(U. S. Forest Service, R-2, 1948)

Species	Volume	
	M bt. ft.	Per cent
Engelmann spruce	13,622,309	61.7
Lodgepole pine	4,689,954	21.2
Alpine fir	1,696,283	7.8
Ponderosa pine	1,217,584	5.5
Douglas fir	801,301	3.6
Other (aspen not incl.)	42,458	0.2
Total	22,069,889	100.0

Lodgepole pine ranks second in importance. Its merchantable volume amounts to nearly 4.7 billion board feet or one-fifth of the total. It

9/ A problem analysis for the Continental Divide Branch of the Rocky Mountain Station which is planned for the near future, will include a more thorough analysis of forest problems on the Western Slope.

occurs most extensively on the Routt and Arapaho National Forests, and less commonly farther south along the Continental Divide.

Other trees of commercial importance include ponderosa pine and Douglas fir. They are confined mainly to the San Juan National Forest, but occur in limited quantities on the Uncompahgre and other forests. Quaking aspen occurs rather extensively throughout the territory where fires have destroyed the coniferous forest.

Most timber stands are scattered due to the rough topography and highly variable environment of the region. The trees are comparatively small and logging is difficult and costly in many areas. Efficient methods of utilizing the timber resource have not been developed. Only the more readily accessible timber has been cut, but fires and insects have taken a rather heavy toll of remaining stands. Although forest growth probably exceeds annual drain, it is far short of its potential. Most of the merchantable timber is overmature and is producing little new growth.

The severity of the present bark-beetle epidemic may be attributed to the presence of overmature stands in relatively unthrifty condition. Though entire stands have been wiped out, a recent survey indicates that spruce reproduction is ample for restocking the area. The present major problem is how to salvage the dead timber economically without undue damage to the reproduction.

Regeneration of Engelmann spruce in mesa-type stands presents a problem due to its frequent association with alpine fir, aspen, and mountain grassland. To prevent alpine fir from dominating spruce sites, this low-value species must be harvested with the spruce, sometimes at a loss to the operator.

Opening of stands, even through light cutting, may result in the invasion of aspen or grass and prevent spruce from reproducing. Windthrow is also fairly common in cut-over stands where 40 per cent or more of the volume is removed.

Scattered reproduction of conifers is generally present in aspen stands. These stands are of considerable importance for grazing, but as the conifers develop, grazing values will decline. Aspen is invading grassland parks in many areas, apparently reducing the forage supply.

Management of forest stands on a sustained-yield basis is hampered by lack of accurate knowledge of growth, efficient cutting methods, and proper cutting cycles. Logging is confined mainly to overmature stands and very little work has been done in timber-stand improvement.

Timber harvested in 1951 amounted to 105 million board feet, or three-fourths of the total harvest in Colorado. Most sawmills are small, portable units, sawing less than 1 million board feet annually. Principal forest products include rough lumber, poles, posts, railroad ties, and mine timbers, practically all of which are used locally. Some dead spruce is now being shipped to the Lake States for use as pulpwood.

The Wildlife Resource

Western Colorado is noted for its excellent hunting and fishing, and expenditures of sportsmen amount to a substantial sum each year. Some kinds of wildlife are harmful and result in economic loss to the region, while nearly all kinds present problems in the management of other renewable natural resources.

Recent estimates place the population of deer and elk in Colorado at 300,000 and 45,000 respectively. Nearly 80 per cent of these animals range in western Colorado where they spend the summer at high altitudes and migrate to lower lands for the winter. Much of their winter range has been severely overgrazed. The poor condition of these ranges naturally limits the number of big game the country will support. Competition for forage between game and livestock is apparent where the choice and abundance of plants is limited.

Trout thrive in most of the streams and lakes of the high mountains. However, many streams at lower elevations have been rendered unsuitable for game fish as the result of poor watershed management or diversion and storage of water for irrigation. Where watersheds have been misused by livestock, streams are often turbid with silt. Some streams dry up quickly after snow disappears in the spring, but become raging torrents during cloudburst storms of the summer.

Upland game birds and migratory waterfowl are of comparatively little importance in the region. While habitats of birds such as sage grouse and ptarmigan are sometimes destroyed by livestock, cover conditions for pheasant, quail, and waterfowl are often improved as the result of irrigation developments.

Small rodents are perhaps more important in retarding recovery of depleted ranges than is generally recognized. They clip the seedstalks of scattered

grasses, devour the seed, and consume considerable quantities of forage. Pocket gophers are especially numerous on the White River, Grand Mesa, and Gunnison National Forests and locally abundant elsewhere at high altitudes. According to estimates by Moir (18), these rodents consume or destroy nearly 30 per cent of the forage crop on national forest summer ranges. In concentration areas as much as 50 per cent of the ground surface may be covered with soil excavated from their tunnels.

Recent studies on Grand Mesa indicate that pocket gophers are detrimental to watershed values, reducing the rate at which water is absorbed by the soil.

Predatory animals are common in western Colorado, but they are kept under control by licensed hunters, trappers, and employees of the U. S. Fish and Wildlife Service. Although predator control is necessary to prevent undue loss of livestock, it is probably responsible for increased rodent populations. When present in large numbers, rodents may cause more damage to the range than predators cause to livestock.

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